IRC:SP:83-2008

GUIDELINES FOR MAINTENANCE, REPAIR AND REHABILITATION OF CEMENT CONCRETE PAVEMENTS

INDIAN ROADS CONGRESS
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FOR
MAINTENANCE, REPAIR AND REHABILITATION OF CEMENT CONCRETE PAVEMENTS

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(28th March, 2008)

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GUIDELINES FOR MAINTENANCE, REPAIR AND REHABILITATION OF CEMENT CONCRETE PAVEMENTS

FOREWORD

The Rigid Pavement (H-3) Committee of the IRC was reconstituted in January, 2006 with the following personnel:

Sinha, V.K.	......	Convenor
Jain, R.K.	......	Co-Convenor
Kumar, Satander	....	Member-Secretary

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Reddi, S.A.	Thombare, Vishal

The Rigid Pavement (H-3) Committee during its 1st meeting held on 9th May, 2006, expressed the urgent need to bring out guidelines on maintenance and repair of rigid pavements in view of the large scale ongoing construction of rigid pavements in the country. It was felt that, at present, there is no comprehensive guideline to tackle the emerging repair problems of cement concrete

pavements in the country. It was further felt that the existing IRC Codes have become outdated in the present day context and need to be suitably amalgamated with the proposed Guidelines. Mr. Noel Boniface (Team Leader, (Meinhardt (Singapore) Pte Ltd. Package III A & III C, Allahabad) and Mr. Ashutosh Gautam, General Manager (Technical), NHAI and Project Director, PIU, Kanpur, Package II A, II B and II C were entrusted with the responsibility of preparing the initial draft, based on their experience in constructing and repairing of the World Bank funded National Highways Development Project (NHDP) on NH-2. The main essence of this document evolves around the 5 level distress systems given in **Table 4.4** and **4.5** which have been adopted from various maintenance reporting systems used by road and airport pavement maintenance agencies around the world.

This draft was discussed by Rigid Pavement Committee in its 5th meeting held on 8th October, 2007 wherein it was decided to constitute a Sub-Group comprising following members to examine the draft and to suggest modifications and improvements:

V.K. Sinha
R.K. Jain
Noel Boniface (Special Invitee)
Ashutosh Gautam
Satander Kumar

The personnel of Sub-group worked on the document and the modified draft document was discussed at length during the 6th meeting of Rigid Pavement Committee held on 19th January, 2008. In view of the comments received from members during the meeting, the draft document was further modified by Shri V.K. Sinha, Secretary General, IRC & Convenor, H-3 Committee and Shri R.K. Jain, Co-Convenor, H-3 Committee after consulting International literature and some members of the Committee to ensure that the document became comprehensive. The finalized draft document was approved by the H-3 Committee in its 7th meeting held on 24th March, 2008. The modified draft document was, thereafter, placed before the Highways Specifications and Standards (HSS) Committee on 28th March, 2008 and the same was approved by the HSS Committee subject to incorporation of comments of the members of HSS Committee. The revised draft document incorporating the comments of the HSS Committee, was presented by Shri V.K. Sinha along with S/Shri R.K. Jain, Ashutosh Gautam and Satander Kumar before the 185th Council Meeting held on 11th April, 2008 at Aizawl (Mizoram). The draft document, after detailed discussions, was approved by the Council for printing as one of the Special Publications of IRC.

For preparing this document, literature published by organizations like FHWA, NCHP, BIS, H.S. Milden Hall and GSD Northcott has been consulted. Indian Roads Congress acknowledges with thanks. The kind permission given by American Concrete Pavement Association (ACPA) to use some of their Figures and Tables in the text of this document. These adaptations, wherever used have been appropriately referred. The IRC also thanks other organizations, whose literature has been referred for bringing out this document. The IRC committee also acknowledges the help rendered by Shri Rajesh Madan of M/s IRCON and the hard work done by the Members of the sub-group and the IRC Secretariat in bringing out this document in its present shape.

1. INTRODUCTION

1.1. Concrete Pavements also known as Rigid Pavements have a relatively long service life, provided these are properly designed, constructed and maintained. With mega projects like National Highway Development Project (NHDP) and Pradhan Mantri Gram Sadak Yojana (PMGSY) the pace of concrete pavement construction has increased recently. This is, because concrete pavements are known to perform better with minimum maintenance. The concrete pavements can serve upto its design service life and even beyond, if timely repairs are undertaken. Load transfer mechanism of the concrete pavement is through beam action and accordingly the concrete pavements are expected to perform relatively better than flexible pavements on weak sub-grades, as these can bridge small soft or settled areas of sub-grades. Design of concrete pavements is fundamentally governed by the flexural strength instead of compressive strength.

1.2. Concrete as a material for pavements gets its strength by effectively resisting loads due to its flexural strength and the pavement can gain a further about 10% strength over its life. The design and construction of rigid pavements is covered in the following IRC publications:

- IRC: 15 – "Standard Specifications and Code of Practice for Construction of Concrete Roads"
- IRC: 43 – "Recommended Practice for Tools, Equipment and Appliances for Concrete Pavement Construction"
- IRC: 44 – "Guidelines for Cement Concrete Mix Design for Pavements"
- IRC: 57 – "Recommended Practice for Sealing of joints in Concrete Pavements" (First Revision)
- IRC: 58 – "Guidelines for the Design of Plain Jointed Rigid Pavements for Highways"
- IRC: SP: 17 "Recommendations about Overlays on Cement Concrete Pavements"
- IRC:SP: 76 "Tentative Guidelines for Conventional, Thin and Ultra Thin Whitetopping"
- MoRT&H – "Specifications for Road and Bridge Works (Fourth Revision)"

References for further information on rigid pavements are shown in **Appendix A:**

1.3. The provisions of IRC:77-1979 which deals with "Tentative Guidelines for Repair of Concrete Pavements using Synthetic Resins" are already incorporated in these guidelines. IRC: 77-1979, therefore, stands withdrawn.

1.4. The **Figs 1.1 to 1.3** depict broad arrangements of three main types of concrete pavement i.e. Jointed Plain Concrete Pavement (JPCP), Jointed Reinforced Concrete Pavement (JRCP) and Continuously Reinforced Concrete Pavement (CRCP). **Fig. 1.4** depicts a typical cross-section of rigid pavement. These Figures are given to facilitate better appreciation of the different types of rigid pavements and associated distresses.

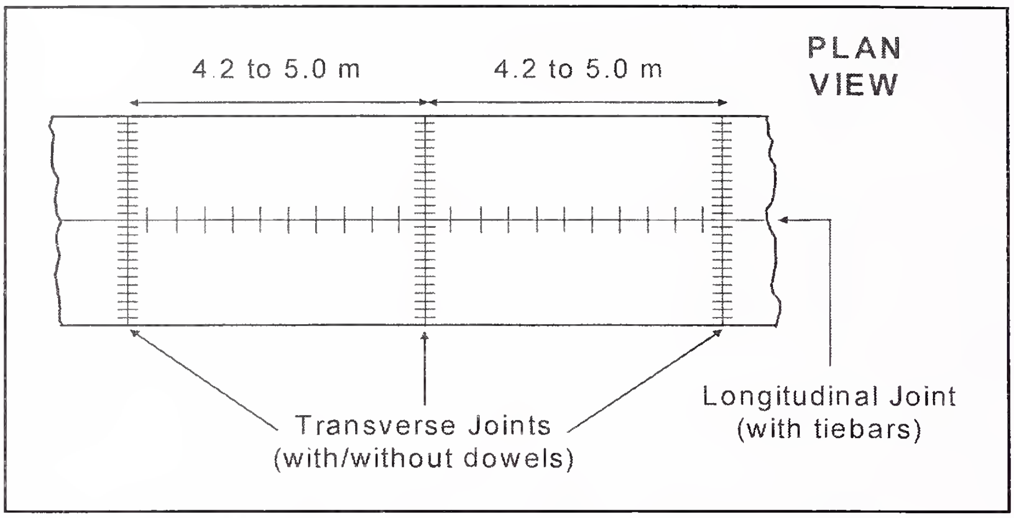


Fig. 1.1. Jointed Plain Concrete Pavement (JPCP)

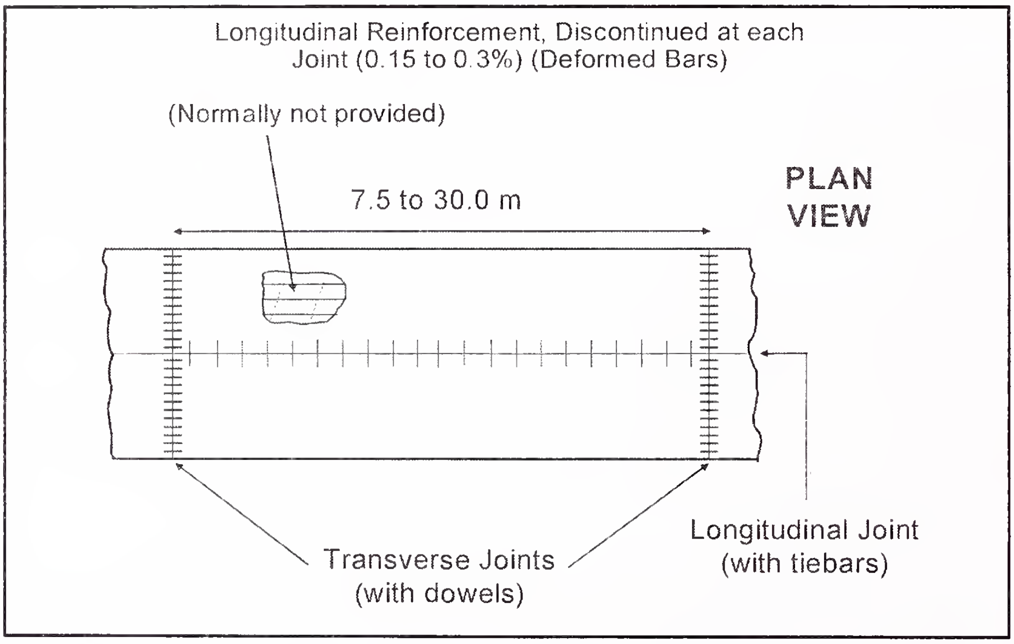


Fig. 1.2. Jointed Reinforced Concrete Pavement (JRCP)

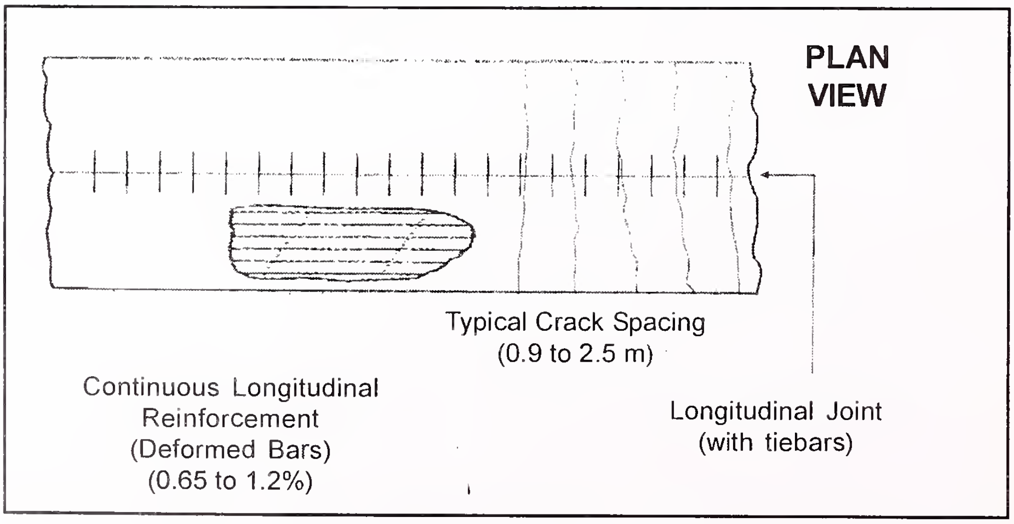


Fig. 1.3. Continuously Reinforced Concrete Pavement (CRCP)

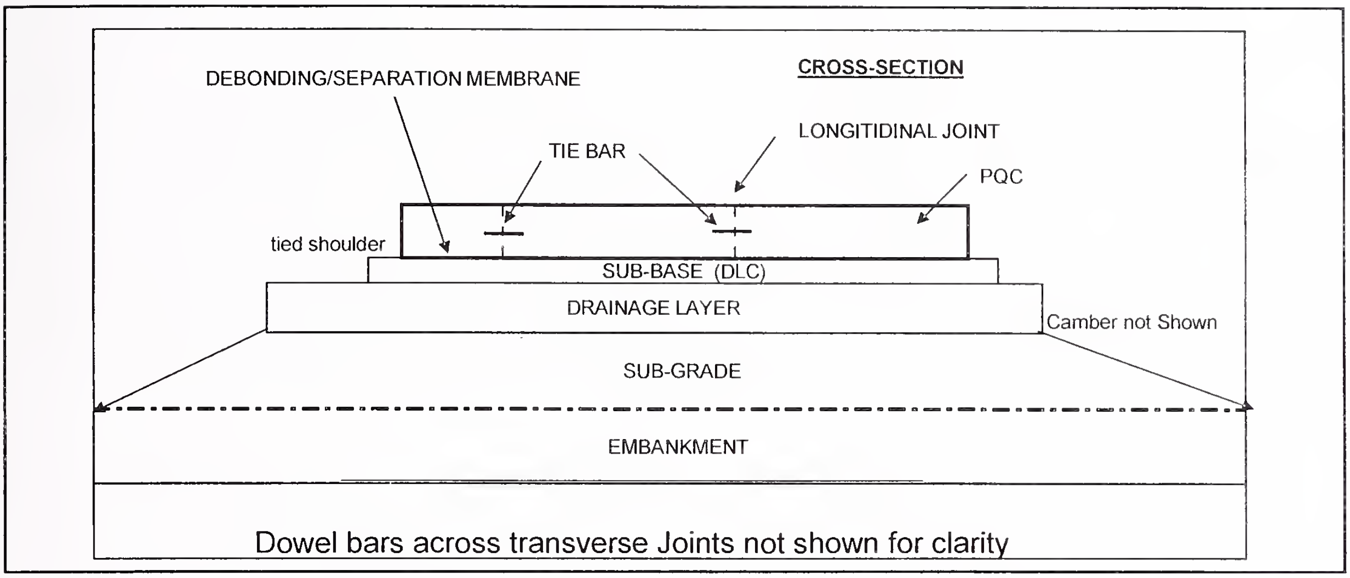


Fig. 1.4. Rigid Pavement Typical Cross-section

1.5. The concrete pavement slab expands with the rise in temperature and contracts with fall in temperature. Concrete shrinks as it cures. Concrete slabs accordingly curl and warp due to the temperature and moisture gradients. This expansion and contraction is resisted by the mass of the concrete slab. The natural responses due to the above, causes concrete pavement to crack at fairly regular intervals. Keeping this in mind, contraction joints are provided at designed/ designated intervals to take care of the expected cracking. Contraction joints are thus provided to ensure that cracking in concrete slabs do not take place at other locations except at the contraction joint locations. It is presumed that if contraction joints are properly located, designed and constructed, cracks at other locations will normally not take place. However, uncontrolled (random) cracks in the concrete pavement do take place at undesignated locations due to various factors including deficiencies like inappropriate selection of materials, lack of timely and adequate curing, too delayed/too early sawing of the joints, construction deficiencies etc. Faulting, Scaling, Loss of texture etc. are other types of distresses which are normally encountered in concrete pavements. These distresses are mainly due to improper functioning of joints, settlement of sub-grade, loosening of tie bars and improper construction workmanship.

1.6. Cracks are not uncommon to concrete construction and, therefore, minor shallow cracks need not be viewed as a serious problem. Many cracks can be restored easily to a condition that will serve for the design life of the pavement. In some cases, no repair may be required, while in others some preventive repairs like resealing, retexturing will be sufficient. Only deep structural cracks are a matter of serious concern for which repair methods are available. These guidelines apart from suggesting various repair techniques are also aimed to offset the impression that the repairs of the concrete pavements are something impossible and therefore, their construction should be avoided.

1.7. Scope

1.7.1. All pavements deteriorate with time. The rate of deterioration of concrete pavement is comparatively much slower than the flexible pavement. The concrete pavements are therefore expected to have a longer service life. **Fig. 1.5** indicates the typical treatment which may be considered with the age of pavement. In the case of concrete pavements, some distresses at a few isolated locations, however, do take place immediately after or during an early stage after completion. If these isolated distresses are rectified well in time, then longer life of the concrete pavement is assured without much need of detailed periodic maintenance/rehabilitation. Preservation of concrete pavements can be broadly classified into three categories :

(i) **Concrete Pavement Restoration (CPR) Techniques** - Repair and maintenance operations without any overlay.

(ii) **Rehabilitation** - Strengthening involving overlay options.

(iii) **Reconstruction** - Undertaken after the end of service life or due to severe distresses in longer stretches due to faulty design/construction.

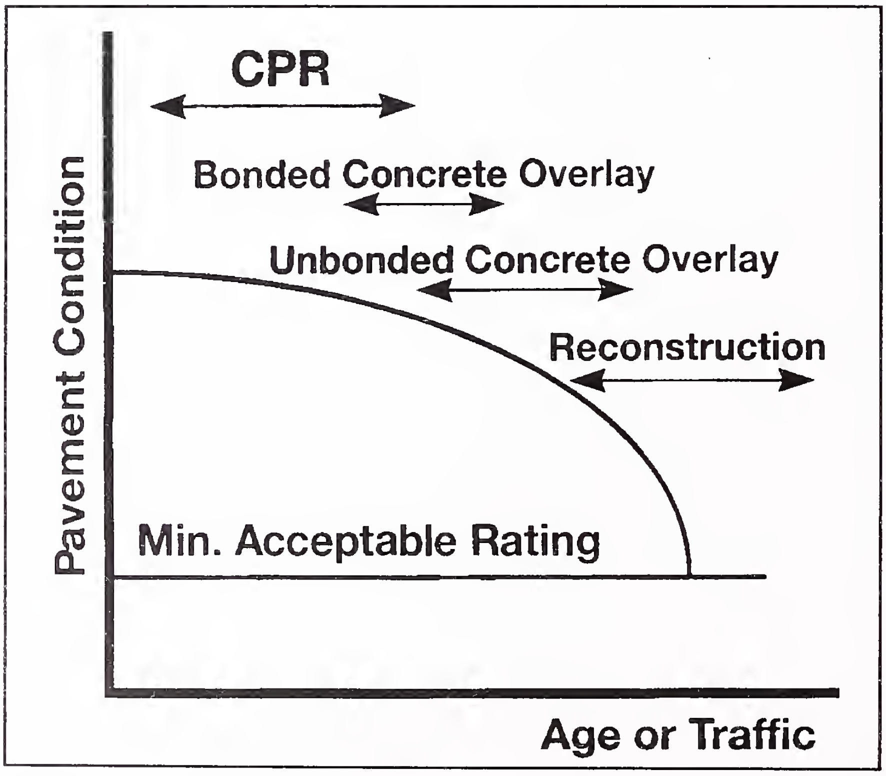


Fig. 1.5. Maintenance Strategy of Ageing Pavements with level of Deterioration (Published by permission of the American Concrete Pavement Association, Copyright, 2008)

1.7.2. The actual treatment required to be given to concrete pavement will depend on the deterioration characteristics and also on the extent of deterioration. **Fig. 1.5** shows different

methods that can be applied to arrest further deterioration due to distress and ageing effect. They range from isolated repairs undertaken by way of Concrete Pavement Restoration (CPR) technique to overlays and finaly to reconstruction.

1.7.3. With proper design, construction and maintenance, a concrete pavement is expected to give a useful service life of more than 30 years without any significant rehabilitation/reconstruction. Concrete Pavement Repairs/maintenance involves a series of engineering techniques which are used to repair the isolated areas of distress. Broadly such repairs theoretically do not enhance the structural capacity beyond the designed life of a concrete pavement. In reality such repairs, however, do extend the service life of the pavement. Timely repair by adopting CPR techniques is quite cost effective and helps to avoid costly rehabilitation/reconstruction later on.

1.7.4. There could be situations, where one or more repair techniques may be required to be used together to mitigate distresses. In some cases, where more than one repair technique is required to rectify the defects/distresses, these will be executed in a proper sequence to ensure the effectiveness of such repairs. Repair and maintenance strategies suggested in these guidelines are basically intended for old pavements. In case of new construction for which the defect liability period is not yet over, the relevant contractual clauses will prevail notwithstanding the recommndation made in these guidelines. In case of newly constructed pavement, these guidelines may be referred subject to the provisions of contractual clauses (Refer Para 5.3). Guidance may be taken for the preparation of the contract clauses for new construction for which defect liability period is not yet over. These guidelines address the need for cost effectiveness and consideration of lane closure problems encountered during the operation phase which should normally occur much after the construction phase. The present guidelines are primarily focussed on repair/maintenance of the concrete pavements through CPR techniques.

1.8. This document has 15 Chapters dealing with the different aspects of survey, identification of distresses and repair methodologies. Besides this, there are 5 Appendices. **Appendix-A** provides a long list of References of specialist literature which may be referred for further information. **Appendix-B** gives typical characteristics of a new concrete type, namely, Earlier Opening to Traffic (EOT) concrete as adopted in some of the projects in USA. EOT concrete is an emerging material and is being used recently to reduce the lane closure period. By adopting EOT concrete it has been possible in USA to open such repaired stretches to traffic in 6 to 24 hours after the repair. The Technology, however, is not yet fully proven and therefore details furnished in **Appendix-B** is just informative and indicative. **Appendix-C** is significant and should be referred by the reader before reading the Guidelines because it gives a general perception about the different types of distresses, about the degree of severity of distresses and about likely treatment to be provided. **Appendix-D** gives suggestive treatment for eroded earthen shoulders which is a common distress observed on our Highways. **Appendix-E** gives details of Mu-meter and British Pendulum Tester.

2. DEFINITIONS

2.1. General

The main types of maintenance required in respect of cement concrete pavements are as follows:

(a) **Routine Maintenance:** It embraces the proactive work items which are required to be carried out in a consistent scheduled (almost regular) basis around the year, such as monitoring the condition of the pavement, keeping the pavement and joints clean and free of stones and debris, restoring damaged and eroded shoulders and other such road side activities which can be generally managed in a day or so in one particular stretch.

(b) **Programmed Maintenance:** It covers the reactive spot/incidental repairs such as filling of popouts/potholes with specified materials and other generally planned activities such as resealing the defective joint sealant, cross-stitching, partial depth repairs, full depth repairs and diamond grinding to remove faults in the rigid pavement.

(c) **Rehabilitation and Strengthening:** It refers to major restoration or upgrading of the pavement like diamond grooving for restoring surface texture, slab stabilisation, reconstruction or application of an overlay to rectify structural inadequacy in the pavement over lengths typically in the range of 1 km or more and thus to extend the serviceable life of the pavement.

(d) **Emergency Repairs:** It covers responding to complaints or emergencies.

The repairs are usually performed by skilled (sometimes specialist) labour engaged on a periodic and planned basis.

2.2. Terms and Definitions

Different terminology used in these guidelines will be read in accordance with the following definitions/abbreviations:

Blowup or Buckling Compressive failure in which there is either upward movement of both or one slab ($>$ 4 mm) or shattering of one or both slabs at a joint or a crack.

Bump Local areas at a higher level than the pavement profile.

Composite Pavement A pavement consisting of flexible over rigid or rigid over flexible.

Corner Break Diagonal full depth crack that intersects the corner joints at less than a half width of the panel.

Cracks:

Corner Crack Cracking that extends diagonally across corners (generally within 600 mm of the corner).

Crack along Joint Initial phase of spalling, crack intersects the joint at an angle and travels parallel to it.

Crow Foot or Y Shaped Cracks Deep shrinkage cracks (more than 25 mm) resulting from excess of water or water basins on the top surface of the slab.

Crazing (Fine Alligator Cracking) Shallow fine alligator cracking or cracking in all directions that results from inappropriate surface finishing and may develop into ravelling.

Diagonal Crack Linear crack that extends diagonally across the slab.

Durability "D" Cracks Family of closely spaced, crescent shaped fine cracks that initiate at slab corner/joints/cracked corners and run close and parallel to slab edges and may result from chemically reactive aggregates and differential expansion of large aggregates. Cracked areas are usually darker in colour. "D" cracking generally starts at the slab bottom and moves upward.

Fine/Hairline Cracks Shallow surface cracks which have an unspalled width of less than 0.2 mm at the surface of the slab.

Longitudinal Cracks Linear cracks running approximately parallel to the pavement centre line.

Map/Aligator Cracking Cracks forming a rectangular (map) or irregular polygonal pattern (like an alligator skin).

Narrow Crack A crack which has an unspalled width of up to 0.5 mm at the surface of the slab.

Multiple Cracks Multiple connecting cracks which are not in a straight line.

Medium Crack A crack which has an unspalled width of between 0.5 mm and 1.5 mm.

Parallel Cracks Usually fine cracks forming a family, more or less parallel to one another.

Plastic Shrinkage Cracks Family of regularly spaced, parallel, shallow cracks in the pavement surface resulting from plastic shrinkage during the early age of the concrete (24-48 hour) in hot/windy conditions and/or inadequate curing. These do not normally extend to the edges of the slab.

Reflection Crack A crack in an overlay which occurs over a crack or a joint in the underlay.

Transverse Cracks Linear cracks running at approximately right angles to the pavement centre line.

Wide Cracking A crack which has an unspalled width exceeding 1.5 mm at the surface of the slab.

Working Crack Transverse crack extending full width of slab with depth (d) greater than half the slab depth (D/2) which artificially create joint location.

Curling - Curling is distortion of the pavement slab from its proper plane caused by differential expansion or contraction resulting from a difference in temperature between the top and bottom of slab. **Fig. 2.1** illustrates distortion of pavement slab under different temperature gradients.

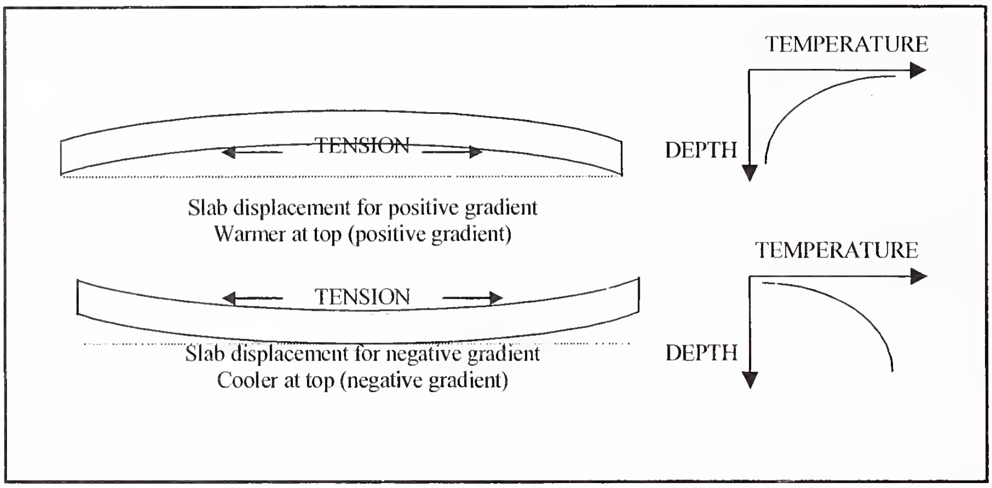


Fig. 2.1. Distortion of Pavement Slab under Different Temperature Gradients

Damaged Surface Hardened surface deeply abraded or otherwise damaged following accident, or by vehicle tracks or metal wheels.

Depression Localised section at a lower level to the normal pavement profile. This usually happens due to inadequate care at the time of laying.

Diamond Grinding (cutting) Method that uses a series of diamond tipped saw blades gang-mounted on a shaft for correcting irregular surfaces in concrete pavement that are commonly caused by faulting, curling and warping of slabs. This is also applied to the pavement surface to restore skid resistance.

Divided/Broken/ Shattered Slab Cracks in different directions dividing a slab in a number of pieces. Such cracks may intersect and may also converge in a point. In case of shattered slab the pieces are not less than four in number.

Dowel Bar Retrofit Method for providing /restoring load transfer under the wheel paths in an old undoweled or doweled pavement or transversely cracked concrete slabs by installing dowels into slots cut into the pavement surface so as to extend the service life of the pavement slab.

Dowel Socketing The widening of the dowel hole, which leads to loss of load transfer.

Drop Off Settlement between traffic lane and bituminous/soft shoulder following erosion or wear or secondary compaction of shoulder by traffic. The shoulder is at a lower level than the concrete pavement.

Faulting (or Stepping) Difference in elevation across joints or cracks, creating a step of 4 mm or more in the pavement profile and may be transverse or longitudinal (positive or negative).

Foreign Matter Foreign incompressibles like aggregates usually impregnated in the joint/ joint sealant that may initiate spalling or locking of transverse joints.

Full Depth Repair Repair involving the replacement of part or whole slab to the full depth of the slab.

Functional Characteristics Characteristics of the pavement which are important to users, including safety and riding comfort.

Heave Localised failure where an upward bulge took place.

Impressions Impressions that may be associated with depressions left in fresh concrete, by movement of animals/vehicles/bicycles.

International Roughness Index (IRI) Representation of the pavements longitudinal surface profile/riding quality expressed in units of "m/km".

Intervention Level/ Standard Maximum permissible tolerance level at which a defect is to be promptly scheduled for rectification.

Joints:

Longitudinal Joint Sawn or formed joint parallel to the centreline intended to relieve stresses due to warping. Usually placed between lanes.

Transverse Joint Sawn or formed joint normally placed at regular intervals at right angles to the centre line intended to act as a contraction/construction joint.

Construction Joint Full depth butt joints placed wherever construction operations require to prevent a cold joint forming. Usually when paving operations stop for more than 1/2 hour or at the end of a day's paving.

Contraction Joint Sawn or formed joint normally placed at regular intervals intended to relieve tensile stress in the concrete and to so prevent formation of irregular cracks in the slabs.

Expansion Joint Butt joint with space into which the pavement can expand. These joints have normally compressible fibre board/synthetic board and are doweled.

Loss of Fine Aggregate/Exposed and Polished Coarse Aggregate Fine aggregate loss around the coarse aggregates that show a rounded polished surface.

Loss of Surface Texture Level of surface texture is a measure of smoothness of concrete pavement surface. With time the texture gets smoothened due to abrasion. Smoothening of surface texture is measured by following three methods: (i) Sand Patch Method (ii) British Pendulum Tester, (iii) Mu-Meter

Manhole or Inlet Failure Cracking and/or faulting following restrained thermal movements around a manhole or inlet.

Overlay:

Bonded Overlay A thin concrete overlay in direct contact and adhering to the existing concrete which provides increase in the pavement structure. Used to correct functional or structural deficiencies.

Unbonded Overlay A thick concrete layer on the top of an existing concrete pavement uses a separation interlayer to separate the new from old/existing concrete.

Whitetopping A rehabilitation technique associated with asphalt pavements comprising a thin concrete overlay placed directly over and bonded with the existing asphalt surface. Not applicable to concrete pavements. For more details, refer IRC:SP:76-2008.

Partial Depth Repair Replacement of damaged concrete after vertical saw cuts are made in a regular rectangular shape in the upper 1/3rd depth of the slab.

Pateching Removal and replacement of an area of pavement with new material.

Pavement Lock-up The inability of the joint or crack to open and close with temperature changes.

Performance Standard The performance standard defines the minimum level at which of the facility is to be maintained and operated for the safe passage of traffic.

Popout (Small Hole) Small hole left in the pavement surface by oversized particles of soft aggregates, clay lumps or other soft/foreign materials getting mixed in the concrete rising to the top and breaks loose under traffic: normally 25 mm to 100 mm diameter and 10 mm to 50 mm deep.

Polished Surface (Glazing) Surface that has become flat and polished following the wearing away of the mortar over coarse monomineral or soft aggregates.

Pothole Large hole in the pavement surface generally larger than 150 mm (diameter) x 50 mm (deep) resulting from loss of pavement material under traffic.

Punchout Partial area of a slab broken out by several cracks particular to continuously reinforced concrete slabs.

Pumping Ejection of fine grained material and water from underneath the pavement through joints, cracks or pavement edge caused by the passage of traffic rolling over the slab.

Ravelling	Loss of fine aggregates and hardened cement paste/laitance from the surface through abrasion that may or may not have been previously cracked.
Rehabilitation	Structural enhancement that extends the service life of an existing pavement and/or improve its load carrying capacity.
Roughness	Term used for describing the unevenness/riding quality of the pavement as a whole. It is different from texturing for skid resistance.
Scaling	Peeling off the upper part of slab surface (5 mm to 15 mm) following crazing or improper surface finishing.
Sealant:	A material that is applied as a liquid that has adhesive and cohesive properties after curing used to seal, joints and cracks against the entrance or passage of water and or other debris.
Hardening (Oxidation) of Compression Seals/ Sealants	Overdue replacement of sealant that got hardened by oxidation or action of UV rays.
Lack (Absence) of Sealants	Either sealant was not provided or was lost.
Loss of Bond to Slab Edges	Sealant is no more adhering to slab edges, (walls of groove) allows ingress of water and debris.
Overbanding	Overfilling of crack or joint so that a thin layer of sealant spreads onto the pavement surface.
Stripping/extrusion of Sealants	Stripping/pulling out of portions of sealant, loss of bond from the walls of joint groove.
Separation	Existing joint or crack widens; contact and friction of both sections is lost.
Slab	The hardened concrete within the jointed area (Transverse and Longitudinal), typically 4.2 m – 5.0 m (long) x One Lane (wide).
Terminal Slab	Last slab before the deck slab or approach slab (IRC:15).
Transition Slab	Last slab which is laid in steps and partly overlaid with flexible pavement (IRC:15).
Shattered Slab	Cracking in all directions at interface with the longitudinal or transverse joint.
Spalling	Cracking and breaking off or chipping off the upper corner of the joint or crack, that may extend to a certain lateral distance.

Deep Spalling	Multiple cracking and breaking away of concrete adjacent to the joint, often semi-circular in plan and emanating down to the centre of the slab and some times deeper.
Shallow Spalling	The breaking or eroding away of concrete within the depth of the joint groove.
Spalling of joints (Transverse/ Longitudinal)	Cracking, breaking, chipping or fraying of slab edges within 300 mm from the face of the transverse/longitudinal joint.
Stitching:	
Cross-Stitching	Straight normally 12 mm dia. high yield strength deformed bars placed in holes drilled diagonally alternating across a crack (30° approx.) at a predetermined spacing and the holes refilled with epoxy resin.
Stapling	U-shaped normally 16 mm dia high yield strength deformed bars placed horizontally in slots cut 25 mm - 30 mm wide into the slab and the slot refilled with high performance/high strength cement mortar/epoxy mortar.
Structural Characteristics	Structural adequacy of the pavement in relation to its ability to carry future traffic.
Surface Evenness	The roughness of pavement surface is commonly designated as Unevenness Index Value and is expressed in surface roughness and is measured by Bump Integrator (BI). This is expressed in mm/km. Permissible limits shall be as prescribed in IRC:SP:16 – 2004 in units of "mm/km".
Warping	The distortion or displacement of the pavement from its proper plane caused by external forces such as moisture stresses (other than loads and temperature).

3. TYPES AND CAUSES OF DEFECTS

3.1. Distress Identification

A site condition survey once a year, preferably in the beginning of monsoon season should be undertaken to assess the existing pavement condition and to identify the pavement distresses. Such site condition surveys should aim at two objectives:-

(i) To determine the root cause of pavement's distress.
(ii) To track the rate of progression of the distress leading to pavement deteriorations.

Repair techniques discussed in these guidelines, except those of full depth repair, may not be effective, if the rate of pavement deterioration is relatively fast. In case of a fast rate of deterioration particularly in continuous long stretches, the rehabilitation options may be considered along with repair option and appropriate decision taken as per specific site condition. Determining the root cause of failure, if possible, helps in identifying the appropriate repair techniques/strategies including the combinations thereof. The Chapter-4 describes in detail the different types of distress identification/ assessment surveys. It is important to record both the severity and extent of each distress during condition survey undertaken. In case, it is felt that non-destructive and/or destructive testing are required to assess the structural problems, as the same are not adequately determined through visual inspections, then such testing should be undertaken subsequently.

3.2. Distress Types

Distresses in concrete pavements are either structural or functional. Structural distresses primarily affect the pavement's ability to carry traffic load. Functional distresses mainly affect the riding quality and safety of the traffic.

3.2.1. Structural distresses

All cracks are not structural cracks. Any uncontrolled/random crack like longitudinal, transverse, diagonal, intersecting cracks that extends through the depth of the slab (> D/2, where 'D' is depth of PQC slab) is to be considered as a structural crack. Structural cracking is often caused due to excessive loading, long joint spacing, shallow or late sawing of joints, restraint at base or edge, due to joint lock-up, inadequate thickness, material related problems etc. Use of proper construction techniques and traffic load control can reduce/avoid such structural cracks. Often reasons for structural cracking could be pumping of fines from the sub-grade or the sub-base, excessive warping of the slab, subsidence of utility trench, excessive temperature stresses and moisture content. Structural cracks unless repaired effectively reduce the load carrying capacity of the pavement and adversely impact the designed service life of the pavement.

3.2.2. Functional distress

These distresses do not necessarily reduce the load carrying capacity of the pavements but affect the riding quality, and safety. Roughness, loss of surface texture or any other surface related defects, problems like faulting, scaling, ravelling and popouts etc. fall under this category.

3.3. Common Defects and Distresses in Concrete Pavements

3.3.1. Manifestation of distress in cement concrete pavements may be classified in the form of:

3.3.1.1. Cracking :

(a) Plastic shrinkage cracks
(b) Crow Foot or "Y" shaped cracks
(c) Edge cracks
(d) Corner cracks/breaks
(e) Transverse cracks
(f) Longitudinal cracks
(g) Diagonal cracks
(h) Durability "D" cracking
(i) Punchouts

3.3.1.2. Surface defects:

(a) Pop-outs/Small holes
(b) Animal/Wheel impressions
(c) Scaling
(d) Ravelling
(e) Deep abrasion/scooping of surface (following accident)
(f) Polished aggregates/glazing/smooth surface

3.3.1.3. Joint defects:

(a) Spalling
(b) Sealant failure and/or loss
(c) Faulting at joints
(d) Separation at joints

3.3.1.4. Other miscellaneous defects:

(a) Blowups
(b) Pumping
(c) Patch Deterioration
(d) Drop off

The broad causes for common type of defects are given in **Table 3.1.**

3.4. Causes of Common Distresses

3.4.1. Timing of sawing the joints:

3.4.1.1. Timing is very critical. Determination of appropriate timing of sawing requires experience and is also a site specific decision. It depends upon factors like, ambient temperature, wind velocity, relative humidity, type of aggregates used and rate of strength gain etc.

3.4.1.2. International literature suggests that there is a time range during which the activity of sawing should be completed. This time range is known as sawing window. **Fig. 3.1** depicts this sawing window. Experienced saw operators rely on their judgement and to some extent on scratch test to decide as to whether the concrete is ready for sawing. Concrete surface can be scratched with a nail or knife blade to examine how deep the impression is formed. As the surface hardens, the scratch depth decreases. In general, if the scratch removes the texture, sawing should not be undertaken as it will be a case of too early sawing. An experienced crew can always fine-tune the optimum sawing timing. Sawing to appropriate depth is very important and shallow depth sawing will lead to random cracking. The appropriate sawing depth is between 1/4th to 1/3rd of PQC thickness.

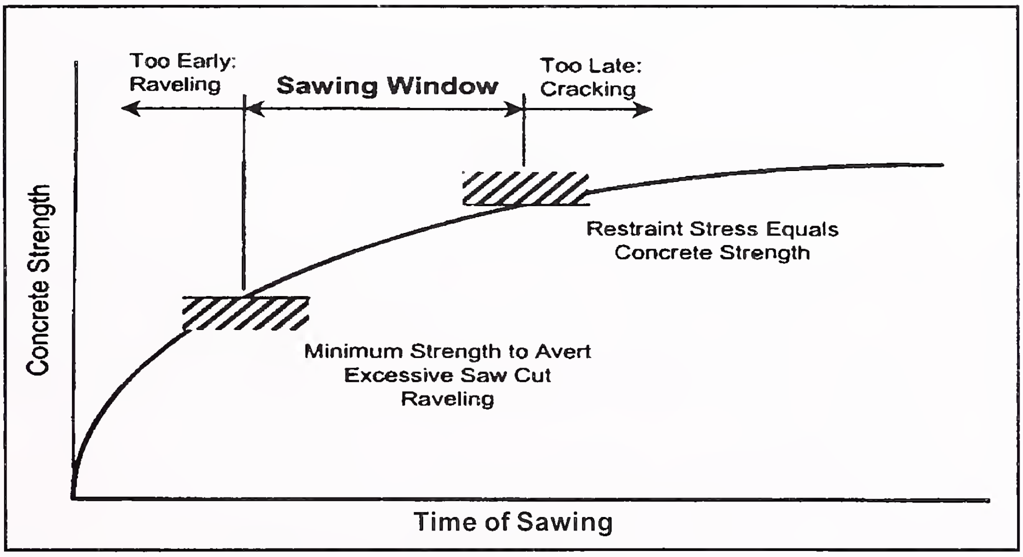
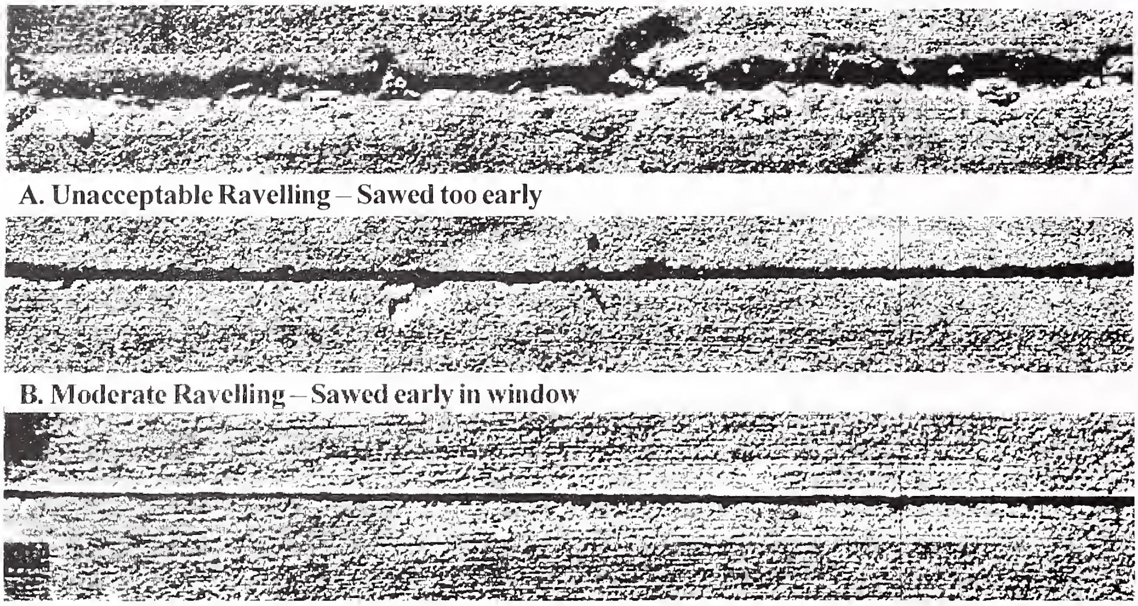


Fig. 3.1 Sawing Window
(Published by permission of the American Concrete Pavement Association, Copyright, 2008)

Too early sawing leads to unacceptable ravelling (see **Fig. 3.2**) and too late sawing leads to uncontrolled/random full depth cracking. Uncontrolled/random full depth longitudinal cracking often occurs due to too late sawing. An early entry dry saw, if applied to a depth of 0.2 times the thickness of the PQC or 25 mm will avoid random cracking. Sawing should not be initiated when the compressive strength of the concrete is less than 2 MPa and should be completed before it

attains the compressive strength of 7 MPa. These figures are indicative only. The actual timing will depend upon ambient temperature, wind velocity, aggregate types, humidity etc. Another way is to saw alternate panels to begin with. This will help to complete the sawing operation within the sawing window range. The left out panels should be sawed subsequently. It should be ensured that these alternate panels are not left unsawed inadvertently.



A. Unacceptable Ravelling – Sawed too early

B. Moderate Ravelling – Sawed early in window

C. No Ravelling – Sawed later in window

Fig. 3.2. Close up of Different Degrees of Ravelling Caused by Joint Sawing (ACPA)
(Published by permission of the American Concrete Pavement Association, Copyright, 2008)

3.4.1.3. Understanding the causes of pavement distress is essential for providing appropriate effective repair and developing maintenance strategies. Contraction joints are provided in the concrete pavement to control the formation of uncontrolled cracks in the concrete pavement. But early uncontrolled cracks do occur for a variety of reasons. It is therefore important to identify the correct causes so that appropriate cost effective method for rectification is selected.

3.4.1.4. Plastic shrinkage cracking: It is important not to confuse cracks arising due to restraint of the concrete at early age due to misaligned dowel bars, improper joint spacing and timing of joint cutting with plastic shrinkage cracks. Plastic shrinkage cracks are tight, about 0.3m to 0.6 m long formed in parallel groups perpendicular to the direction of the wind, at the time of paving. Plastic shrinkage cracking is a result of rapid drying at the pavement surface. The cracks normally extend down to a depth of about 20 mm - 30 mm. Adequate curing measures are necessary to prevent their occurrence. Experience has shown that these cracks rarely influence the overall performance of the pavement, therefore a nominal repair as described in Chapter 5 is normally sufficient.

3.4.1.5. Drying shrinkage cracking: Wider/deeper cracking is usually attributable to the drying shrinkage and restraint developed in the concrete due to inadequate joint spacing, improper

saw cutting or misalignment of dowel bars. The optimum spacing of joints in a jointed concrete pavement depends on the slab thickness, sub-base stiffness and concrete strength. ACPA recommends a maximum joint spacing of 21 times depth of the PQC slab for concrete pavement constructed over dry lean concrete (DLC)/stabilised sub-base. Other agencies recommend even closer joint spacing, so as to maintain the ratio of slab length to the radius of relative stiffness less than 5. The equation 3.1 gives radius of relative stiffness. Pavement with long transverse joint spacing may otherwise develop full panel width deep cracks due to tensile stresses developed due to temperature curling.

$$l = 4\sqrt{\frac{E.h^3}{12\,(1-\mu^2)\,.k}} \qquad \text{(Ref: IRC:58)} \qquad \text{..... Eq (3.1)}$$

Where,

l	=	Radius of relative stiffness, cm
E	=	Modulus of elasticity of concrete, kg/cm^2
h	=	Thickness concrete, slab, cm
μ	=	Poisson's ratio
k	=	Modulus of sub-grade reaction, kg/cm^3

Where, it is necessary to repair/replace the sub-base, a separation membrane or two coats of a wax based bond breaker, shall be applied on top of the new DLC layer before reconstruction of the Pavement Quality Concrete (PQC).

3.4.1.6. Misaligned dowel bars: If the saw timing and saw cut depth are found adequate, cracking could still occur due to the misalignment of dowel bars. The misalignment of dowels can induce a crack away from a transverse joint, if the dowels physically lock two slabs together and restrain their contraction.

3.4.2. Traffic loading and environmental influences

The concrete pavement is further exposed to traffic loading and environmental influences, namely temperature and moisture which can have the following effects:-

3.4.2.1. Traffic related distress causes are the most widespread and frequent. They usually act in combination with climatic causes.

- Axle loads are responsible for fatigue and impact failure of the materials of different pavement layers including the pavement slab. They also originate structural cracking both shallow and full depth and vertical differential movements of the concrete slabs or faulting as well as lateral slab movement.
- Wear by traffic tires results in loss of texture and consequential functional distress of the pavement surface

3.4.2.2. Temperature related distress of concrete slabs results from temperature variations and gradients along the slab thickness.

- Thermal expansion or contraction is resisted by friction of the underlying layer and by the adjoining slabs and compressive/tensile stress builds up during expansion/contraction that may originate cracking.
- Temperature gradients also initiate slab curling and loss of uniform subbase support, which may lead to cracking including structural cracking.

3.4.3. Moisture decreases the bearing capacity of underlying layers, facilitates abrasion and internal erosion. Surface water ingress in the pavement structure shall be prevented by properly sealed joints and by timely sealing of cracks. However sealing materials deteriorate with time and therefore a properly designed and operational pavement sub-surface drainage shall be provided so that any percolating water does not remain entrapped within the pavement. If these conditions are not fulfilled and water is trapped in or between the pavement layers it will be subjected to high pressure and may be expelled under passing traffic loads carrying fine materials (pumping) in suspension that result from internal erosion of the pavement materials.

3.4.4. Run-off water may carrying with it foreign incompressible materials ingress in joints and cracks.

3.4.5. Repair cannot be durable if distress causes are not found and eliminated. One type of distress can possibly result from several different causes. Less relevant causes need to be eliminated to focus on the main cause/causes. Careful observations and follow-ups are required to discard certain causes which are not relevant to identify the correct ones. Mapping and rating of the distress type may be done adequately, wherever required for this purpose.

3.4.6. In some cases it may happen that distress causes cannot be satisfactorily investigated until the pavement is excavated before carrying out the repair. The necessary excavation should be done at such locations, wherever considered appropriate.

3.5. Diagnosis of Defects

3.5.1. Causes of construction defects can be related to workmanship and work methods as described above, as well as equipment operating condition and adjustment and the properties of the materials.

3.5.2. Unexpected changes in climatic conditions (temperature, moisture, wind) may also originate defects and distress, when appropriate preventive action is not taken.

3.5.3. Construction records and diaries of line supervisors and managers should contain the most important/useful information to identify causes of defects. For example: ambient temperature, speed /direction of wind at the time of paving, time of joint saw cutting, inconsistencies in delivery and/or placing of the concrete, malfunctions of the equipment etc.

3.6. Diagnosis of Functional Defects and Distresses

3.6.1. Functional Performance of the pavement refers to characteristics of the pavement that are important to users. These characteristics primarily include safety (as measured by skid resistance testing by the British Pendulum or Mu-meter Test or texture depth as measured by the Sand Patch test) and riding comfort (as measured by profilograph or bump integrator and in some situations also by noise measurements).

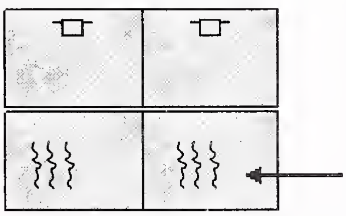
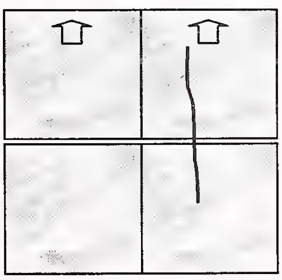
3.6.2. Surface Functional distress results from wearing of the pavement surface materials by traffic tyres and heavy abrasion from vehicle parts during breakdown/accident. Their causes can therefore be found in the volume of traffic, in tangential efforts applied by the tyres, like braking efforts and in the capability of the pavement surface materials to withstand such efforts with minimum wear under the prevailing weather conditions.

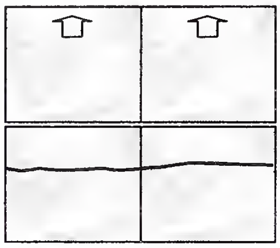
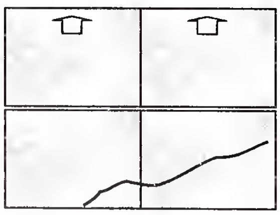
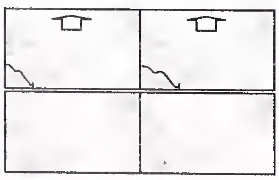
3.7. Diagnosis of Structural Defects and Distresses

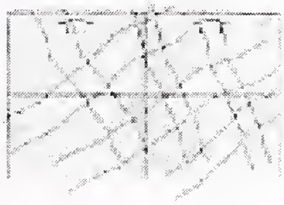
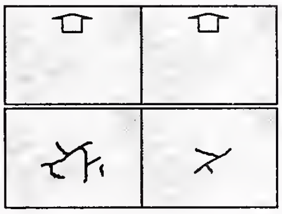
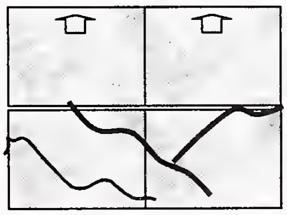
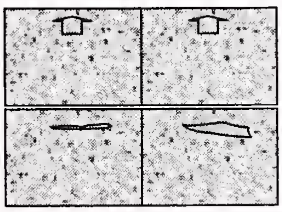
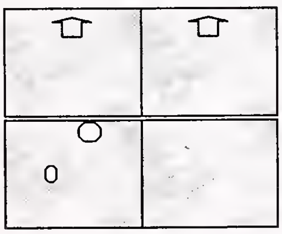
3.7.1. Structural performance refers to the structural adequacy of the pavement in relation to its ability to carry future traffic. Structural adequacy can be determined by performing distress surveys like deflection testing, nondestructive testing, and materials testing.

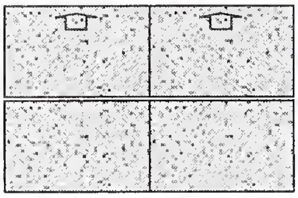
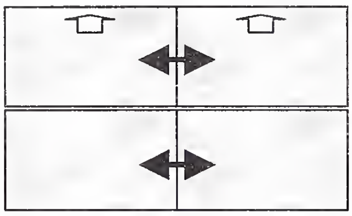
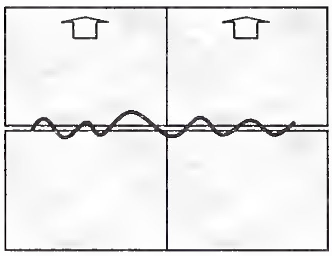
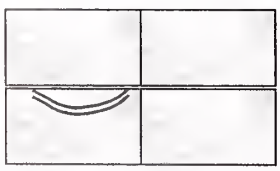
3.8. Table 3.1 gives the details regarding the common type of defects in the concrete pavements and their possible causes.

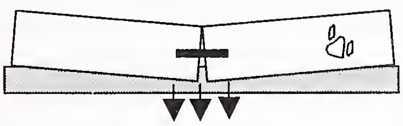
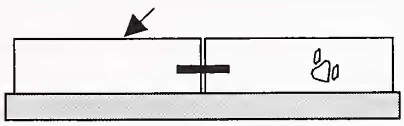
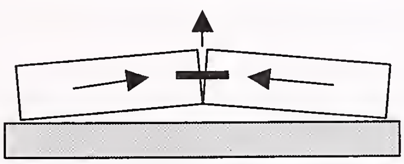
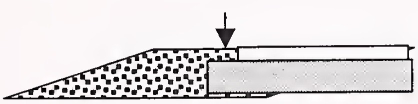
Table 3.1. Types of Defects and Causes

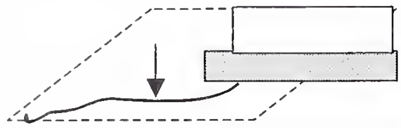
S.No.	Class and Type of Defects	Common Causes
1.	**Cracking**	
	(a) Plastic Shrinkage Cracks Traffic Direction  Wind Direction KEY PLAN	i. Drying shrinkage stresses in surface ii. Poor curing iii. Hot windy conditions iv. Excessive water at surface (bleeding)
	(b) Longitudinal Cracks 	i. Excessive drying shrinkage stresses ii. Inadequate depth of joint or late joint sawing iii. Excessive joint spacing iv. Sudden/abrupt thermal and moisture gradient changes v. Down hill paving; cracks perpendicular to the direction of super elevation

S.No.	Class and Type of Defects	Common Causes
		vi. Channalised or static heavy loading, viz. truck parking vii. Loss of sub-grade support, for instance poorly compacted sub grade viii. Settlement of embankment which leads to subsequent settlement of slabs ix. Different sub-base/sub-grade types having different modulus of elasticity and or moisture regime across the width of the cross-section x. "Vibrator trails" caused by malfunctioning or improper adjustment of vibrators on the paving machine
	(c) Transverse Cracks 	i. Tensile stresses in concrete are more than tensile strength of concrete ii. Excessive drying shrinkage stresses iii. Inadequate depth and/or late initial joint groove sawing iv. Excessive joint spacing or length /width ratio of slab more than 1.5 or length of unreinforced slab exceeds normal range 4.5-6.1 m. v. Misaligned, corroded, locked, burred on ends dowel bars vi. Crack at the end of the dowel bars; or locking of dowel bars vii. Delays or interruption of concrete placing for more than 30 minutes viii. Excessive overloading ix. Sudden/abrupt thermal and moisture gradient stress changes x. Excessive sub base restraint xi. Settlement/poor sub-base support at localized area xii. Incorrect location of transverse joints at/over cross drainage structure/utility duct
	(d) Diagonal Crack 	i. Excessive drying shrinkage stresses ii. Excessive thermal and moisture gradient stresses iii. Excessive joint spacing iv. Unstable sub-grade or loss of sub-base support (settlement of utility trench, etc.) v. Excessive over loading vi. Frost action
	(e) Corner Breaks 	i. The same as diagonal cracks ii. Poor load transfer iii. Dowel bar restraint iv. Curling, thin slabs are particularly susceptible to this cause

S.No.	Class and Type of Defects	Common Causes
	(f) Aligator (Map) Cracking 	i. Coarse aggregate expansion ii. Chemically reactive aggregate iii. Weak concrete iv. Improper curing
	(g) Crazing (Fine/Shallow Cracking) 	i. Over finishing of surface ii. Over vibration of concrete iii. Too rich mix with poor curing and the concrete was not air entrained iv. Poor curing
	(h) Multiple Structural Cracks 	i. Lack of sub-grade support ii. Excessive over loading iii. Weak concrete iv. End of service life
2.	**Surface Defects**	
	(a) Ravelling, Scaling 	i. Segregation at surface ii. Crazing or fine alligator cracks iii. Frost iv. Unsound or dirty aggregates v. Weak concrete (too much water, too much fine aggregate) vi. Inappropriate curing vii. Excessive Abrasion
	(b) Popout (Small Hole), Pothole 	i. Loss of contaminated or non durable concrete pockets at surface ii. Lack of homogeneity, uniformity and consistency of the mix iii. Loss of aggregate from concrete surface: thermal expansion, freeze-thaw iv. Inadequate compaction

S.No.	Class and Type of Defects	Common Causes
	(c) **Loss of Surface Texture, Polished Surface/Glazing/ Smooth Surface** 	i. Movement of construction traffic at an early age ii. Wear and tear under high volumes of traffic particularly under wet or uncleaned surface iii. Poor texturing during construction iv. Soft and monomineral aggregates v. Frequent braking and turning sections vi. Non durable concrete
3	**Joint Defects**	
	(a) **Joint Separation** 	i. Insufficient or incorrect tie bar installation in longitudinal joints ii. Shoulder movement iii. Downhill slipping of slabs on a steep gradient/super elevation iv. Slippage of tie-bars at sharp curves v. High Embankment/black cotton soil
	(b) **Joint Seal Defects** 	i. Hardening (oxidation) or softening by ultra violet radiations ii. Stripping of joint sealant iii. Extrusion of joint sealant: overfilled groove, lack of incompressible caulking strip in bottom of groove, incorrect groove dimensions iv. Adhesion failure/loss of bond between walls of groove and sealant due to: inadequate preparation of groove, inadequate priming, inappropriate sealing material, semi-set/inadequately cured "cold" concrete, moisture in groove; slurry generated due to widening of groove sticking to the walls of groove v. Pressing of small stones and other incompressible matter into the sealant vi. Embrittlement of joint sealant or cohesion failure due to inappropriate sealing material, incorrect groove dimensions, lack of bond breaking strip beneath the seal vii. Inadequate or no tooling to remove air bubbles viii. Inadequate curing before opening to traffic ix. Lack or absence of sealant x. Weed growth in the joints
	(c) **Spalling at Cracks or Joints** 	i. Ingress of stones and other incompressible material into joint ii. Dynamic traffic loads at slab ends, mechanical damage iii. Weak concrete, poorly compacted or non durable, particularly at construction joints iv. Failure or defects of dowel load transfer system

S.No.	Class and Type of Defects	Common Causes
		v. Joints intersection vi. Slab overstressing vii. Spalling at longitudinal joints may be due to faulty construction or cutting of joints, creating slithering or settlement of one lane
	(d) Faulting (or stepping) in Cracks or Joints 	i. Along transverse joints or cracks: build up of material under the approach slab or slab piece; ingress of water internal erosion and pumping ii. Warping or curling following either moisture or temperature gradients iii. Along longitudinal joints: settlement of sub-grade or shoulder drop off caused by heavy traffic iv. Differential settlement/ support due to inadequate foundation / or growth of tree roots v. Reduction in/or lack of load transfer due to separation of slabs
4.	**Deformation**	
	(a) Depression 	i. Differential settlement or consolidation of substrate; ii. Settlement or consolidation of natural ground: compressible soils, peat pockets iii. Development of construction defects such as insufficient compaction in the foundation layers
	(b) Heave 	i. Non stablised expansive soils ii. Upward movement of a slab following material build up under the slab iii. Upward thrust/pressure caused by moisture stresses
	(c) Bump 	i. A local construction defects that may have different causes
	(d) Blow up or Buckling 	i. Accumulation of incompressible material in the joints ii. Excessive expansion resulting from combined adverse thermal and moisture conditions iii. Wrong spacing of joints
	(e) Dropoff (Lane to Shoulder) 	i. Wear and tear from stray and parked vehicles ii. Poor quality of shoulder material i.e. not suited for the purpose iii. Settlement of shoulder iv. Erosion of unpaved shoulder due to surface run-off in rainy season

S.No.	Class and Type of Defects	Common Causes
	(f) Erosion/Undermining 	i. Poor maintenance ii. Inadequate drainage/water interception provisions particularly in super elevated sections
5.	**Inadequate Drainage**	
	(a) Pumping	i. Ingress of water through cracks and damaged joints ii. Poor or inoperational/choked sub drainage
	(b) Ponding	i. Wrong cross-section design ii. Blockage of inlets and or outlets in chute drains and collection pits
	(c) Punchout (applicable to CRCP only)	i. Localised poor concrete ii. Loss of foundation support iii. Poor drainage at edge with paved shoulder

4. ASSESSING MAINTENANCE NEEDS

4.1. General

4.1.1. The evaluation of the exiting pavement condition is the most important part of the process of assessing the maintenance needs. The maintenance strategy will be determined according to the level of deterioration (refer Para 1.7.1 and **Fig. 1.5**). The characterization of the condition of the existing pavement largely determines the types of treatments to be considered. Characterization includes the types of distress, width and depth of crack/defect, percentage area affected; joint defects etc. (refer **Table 4.5**). Different evaluation tests and procedures are available for a complete and comprehensive evaluation of the existing pavement condition.

4.1.2. The maintenance needs should be assessed every year as part of the planning of the road maintenance program. It is recommended that an overall assessment of the maintenance needs be done on the basis of condition surveys which can take various forms such as:

(a) visual rating
(b) profile/faulting/roughness measurements, by profilograph and bump integrator (BI)
(c) deflection tests; by Falling Weight Deflectometer (FWD)
(d) friction/skid resistance tests by sand patch, British Pendulum and Mu-meter
(e) drainage condition survey

4.1.3. Additional testing and measurement will be required to collect specific data particular to the needs identified during the overall condition survey based on repair/rehabilitation alternatives to be considered in the maintenance program. For example, concrete material evaluation, base/sub-base and sub-grade testing and drainage condition surveys. The frequency of such additional testing will depend on the age and extent of damage recorded in the overall condition survey. A review of the project records including plans, specifications, construction quality assurance/quality control records and general inspection notes will be helpful.

4.2. Pavement Evaluation Procedure

4.2.1. Road agencies around the world have developed a range of procedures for evaluation of the concrete pavements in their countries. US Federal Highway Administration (FHWA) has developed 17 numbers standard procedures as given in **Table 4.1.** Some of the commonly used procedures are indicated below:

(a) **Visual Condition Surveys** – Either manual or video/photographic-based procedures can be followed. Specific commentaries are provided to address special features related to PCC pavement distresses.

(i) Visual rating is a simple method of inspecting the pavement surface for detecting and assessing the type and severity of the damage. In most instances, road inspections address all aspects of road condition, including the condition of shoulders, road drainage, road furniture etc., as well as the condition of the pavement.

(ii) Visual condition survey may be conducted from a vehicle driving over the pavement or a manual survey conducted by walking or riding in cycle rickshaw along representative sections. Automated survey equipment are available and may be developed for the purpose.

(iii) Whilst there are various methods of visual rating adopted by different agencies the world over, an essential requirement is to inspect the concrete pavement on a regular basis and record the various maintenance needs kilometer-wise all along the length of the road in standard formats. **Proformae 4.1, 4.2, 4.3** and **4.4** are placed at the end of this Chapter. These proformas are suggestive/ indicative in nature and could be suitably modified in field as per project specific requirement.

(iv) Although slow and labour intensive, the manual condition survey is the most reliable. The best method to record location and extent of distress types in a manual survey is graphical (map) and tabular format. Typical examples for guidance provided are in Proforma 4.1 and Proforma 4.2 respectively. The different types of distress shall be rated and their degrees of severity noted in the forms at the places where they occur.The details may be further summarized in the standard format recommended as in Proforma 4.3.

(v) Any type of distress or defect may be located at a certain pavement section and at a certain distance from the centre line. The same distress may extend in length between two sections across the transverse or longitudinal joints. It may extend laterally to the whole width of the carriageway or only to certain strips or areas. Such extension of distress should be carefully noted to study the extent of such distress.

(vi) The location and extent of the defect/distressed area are recorded as observed at the surface. Since internally deteriorated concrete below the surface can have larger extension than superficial observations may show, before marking the area to be repaired it is important to test the surrounding slab areas.

(vii) The actual extension of deteriorated concrete can be determined by "sounding", which is done by striking the surface with a rod or a hammer or by dragging a chain along the surface. This will produce a metallic ring on sound concrete and a dull/hollow sound on deteriorated concrete.

(b) **Deflection Testing** – This testing is an important part of any pavement evaluation plan. Key aspects are addressed such as the time of testing for PCC pavements,

especially for joint and crack testing, for load transfer efficiency (LTE) and void detection.

(c) **Roughness Surveys** – This is to be done as per IRC:SP:16-2004. Research has established that pavements constructed initially with low roughness level have relatively longer life. There are three methods to assess roughness of the surface as suggested below:

(i) **Sand Patch Method:** As per IRC:15-2002, the value should be between 0.65 mm to 1.25 mm.

(ii) **Measurement by British Pendulum Test:** The value of Skid Resistance Number as per Transport Research Laboratory (TRL, Road Note No. 27), the BPN value should be between 45 – 55 (as per British Pendulum Test) in normal conditions. (Refer **Appendix-E** for more details about the British Pendulum Test).

(iii) **Measurement by Mu – Meter: Appendix-E** gives the acceptable values for Skid Number at different traffic (vehicle) speeds varying from 50 kmph to 110 kmph. (Refer **Appendix-E** for more details about Mu-Meter)

(d) **Faulting Surveys** – The faulting of joint/crack is normally measured with a millimeter scale. However, advance equipment like Georgia Faultmeter if, available may also used for measuring joint/crack faulting.

(e) **Core Testing** – The guidelines refers to standardized testing procedures by the Bureau of Indian Standards (BIS). Core samples may be used for strength testing, and modulus of elasticity testing. Petrographic as well as durability (materials related distress) testing may also be carried with the core samples.

(f) **Ground Penetrating Radar (GPR) Testing** – Guidelines that address ground GPR techniques relative to PCC pavement applications may also be referred.

(g) **Slab Curvature Measurement** –Curling/warping may be determined using the dipstick or by measuring slab deformation (deflections) at slab corners and at other locations using LVDTs or dial gauges. Such testing may be needed in some cases to determine, if premature failure conditions (cracking, etc) are due to excessive slab curling and warping.

(h) **Steel Corrosion Testing** – The guidelines address procedures to identify the state and rate of corrosion of the reinforcing bars at wide cracks and longitudinal joints in Continuously Reinforced Concrete Pavements (CRCP) and Jointed Reinforced Concrete Pavements (JRCP) over time, these measurements provide an indication of the extent of corrosion damage.

(i) **Drainage Surveys** – Drainage evaluation needs to be included as part of overall pavement evaluation, so as to assess any potential future problems caused by moisture

and run-off ***especially*** where the average rainfall exceeds 500 mm per year. The moisture may penetrate the pavement through cracks or transverse/ longitudinal joint due to delamination or oozing out of sealant from the walls of the groove. The condition and effectiveness of side drainage also require recording, particularly, before the monsoon period. The presence of rain cuts, piping and erosion of shoulders should also be recorded. Drainage condition survey data form is given in Proforma 4.4.

Table 4.1 List of Procedures for Pavement Evaluation

Procedure No.	Title
Overall Pavement Evaluation	
TP-1	Visual Condition Survey
TP-2	Deflection Testing
TP-3	Profile Survey
TP-4	Faulting Survey
TP-5	Slab curvature Measurement
TP-6	GPR Survey
TP-7	Friction Testing
TP-8	Noise Measurement
Concrete Material Evaluation	
TP-9	Core Compressive Strength Testing
TP-10	Core Split Tensile strength Testing
TP-11	Core Modulus of Elasticity Testing
TP-12	Core Petrographic Examination
TP-13	Material Related Distress Evaluation
Base/Sub/Base and Subgrade Testing	
TP-14	Base/Sub-base and Subgrade Material Characterisation
TP-15	Dynamic Cone Penetrometer Testing
Drainage Condition Survey	
TP-16	Overall Drainage Survey
TP-17	Corrosion Testing

(*Source:* Report No. FHWA-01-C-00080)

4.3. Function Evaluation

4.3.1. The functional performance of a pavement refers to characteristics of the pavement which are important to the users, including safety (as measured by cleanliness and friction testing) and riding comfort (as measured by profile testing and noise measurements).

4.3.2. The measurement of irrcgularities (roughness) in the road surface can be used to indicate in physical terms the existing condition of the road and its likely deterioration with time. It is thus a very useful tool in the hands of a maintenance engineer. It is good practice to take roughness measurements on the entire network of concrete roads in the country, at least once every three years and to maintain the permanent record of the same.

4.3.3. Moving profilographs or laser devises; are often used to measure the depth of irregularities in the road surface. Standards related to profile measurement and data analysis have been developed by ASTM under ASTM E 950 and ASTM E 1364. The indigenous response type fifth wheel bump integrator (BI) which measures suspension deflections (originally developed by TRRL in the UK) towed over the road surface (preferably in the wheel path) at a steady speed of 32+/-1 km/hour has been generally used in this country to evaluate the roughness in terms of mm/km. A brief description of the above equipment and procedures for calibration are given in the IRC publication “Guidelines for Surface Evenness of Highway Pavements”, IRC:SP:16-2004.

4.3.4. The roughness of a pavement is commonly reported in terms of an unevenness index as measured by the bump integrator. The maximum permissible roughness values (expressed in “mm/km”) recommended by IRC:SP:16-2004 for the roads with different types of surfaces are given in **Table 4.2.**

Table 4.2 Recommended Roughness Values for Roads in India*
(Ref: 1.11- Table 3, IRC:SP:16-2004)

Wearing Type	Surface	Condition of Road Surface					
		Good		Average		Poor	
		BI mm/km	IRI m/km	BI mm/km	IRI m/km	BI mm/km	IRI m/km
Bituminous Concrete (BC)		<2000	2.8	2000 - 3000	2.8 – 4.0	>3000	>4.0
Cement Concrete (CC)		<2200	3.0	2200 - 3000	3.0 – 4.0	>3000	>4.0

* It is possible and desirable to construct roads with roughness level lower than above with the use of modern equipment and construction practices supported with adequate logistics commensurate with the capacity of paver etc.

4.3.5. Two methods of reporting the roughness are commonly followed. One is based on the bump integrator (BI) in mm/km as described above and the other is based on the International Roughness Index (IRI) in m/km. **Table 4.3** gives the conversion values between BI and IRI.

Table 4.3 Conversion BI mm/km to IRI m/km Recommended Roughness Values for Roads
(IRC:SP:16-2004)

IRI (m/km)	1.0	1.2	1.4	2.0	2.5	3.0	4.0
BI (mm/km)	630	770	920	1370	1760	2160	3000

Note: BI in mm/km = 630 x (IRI in m/km)$^{1.12}$

4.4. Structural Evaluation

4.4.1. The structural performance of the pavement refers to its ability to carry future traffic.

4.4.2. There are a number of means of assessing structural capacity by measuring deflection and curvature of the pavement under heavy axle load.

4.4.3. Deflection based non destructive testing methods such as FWD are generally preferred as destructive testing is cumbersome, time consuming and costly.

4.4.4. There are cases when pavement in long continuous stretch is badly damaged and distressed. In all such cases, it may be considered desirable that pavement in such condition be opened up and each layer is tested to identify the exact cause of failure/distress. The Falling Weight Deflectometer (FWD) is a very quick and accurate method for assessing residual life of the pavement, and also for overlay design. The FWD is attached to a 4 wheeled vehicle, and results recorded directly on to computer disc, for later analyses.

4.5. Measurement and Degree of Severity of Defects

4.5.1. The severity of any type of distress can be evaluated by the measurement of one or two parameters that best characterise that type of distress.

(a) Deformation in the pavement may be due to faulting, drop-off shoulder, heaving, blow up etc. Deformation is measured in terms of level difference in mm by using a straight edge and a graduated wedge or tape.

(b) Individual cracks can be evaluated by measuring their width in mm. This can be done by inserting metal strips of standard gauge thickness or by optical microscope. Refer **Figs. 4.1 (a), (b)** and **(c).** Measurement of crack length and its variation with time is also important. Cracks that run across one or more slabs are particularly severe and

result from concrete tensile failure. The maximum crack width shall be recorded as representative of at least 50% of its length.

Fig. 4.1 (a) Optical Microscope for Measuring Width of Crack

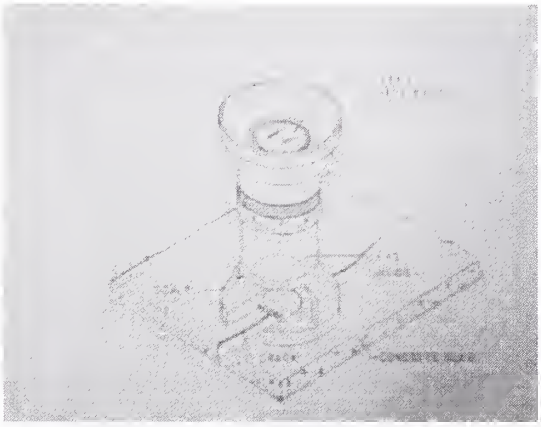


Fig. 4.1 (b) Line diagram of Optical Microscope over a Crack

Fig. 4.1 (c) Measuring Width of Crack with Optical Microscope

(c) Multiple and hair cracks can be evaluated by measuring the total length of cracks in mm/m^2 within a square frame with 1 m long sides.

(d) For cracks, it is also very important to know their depth, because full depth cracks (>D/2) allow ingress of water and undermine the strength of the slab and the pavement. On the other hand some kinds of shallow cracks, such as shrinkage cracks do not need to be repaired if they are isolated and short. The crack depth can be determined in cores bored from the pavement or by ultra-sonic pulse velocity measurements across the crack. The depth as determined by ultra sonic method is about 60 to 70% of the actual depth as determined by the codes method.

(e) Surface loss (ravelling and scaling) can be evaluated by its percentage of damaged area and its maximum depth.

(f) Joint spalling can be evaluated by measuring its width in mm. Refer **Figs 4.2 (a) & (b)**. The maximum spalling width shall be recorded

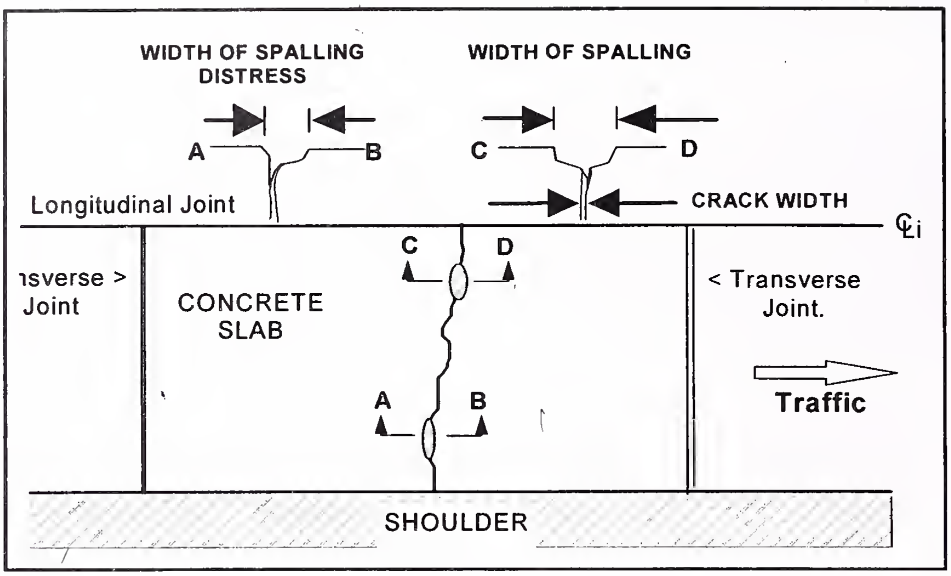


Fig. 4.2 (a) Measurement of Spalling at a Crack

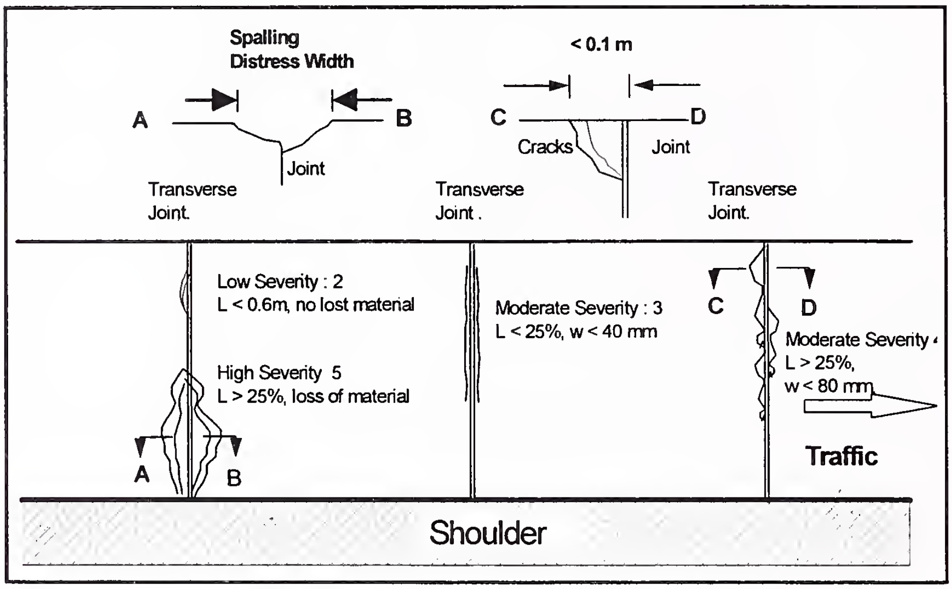


Fig. 4.2 (b) Measurement of Spalling at a Joints

(g) Individual popouts and potholes can be evaluated by measuring their diameters and depths. Multiple popouts can be evaluated by their number per square metre.

(h) Surface wearing can be evaluated by its area density as a percentage and the textural depth (sand patch test) or skid resistance of the worn surface.

(i) Patching can be evaluated as the percentage area patched to the total area of the slab.

4.6. Distress Rating System

4.6.1. The routine survey and recording of the surface condition and rating of severity of defects is important for assessing the maintenance strategy. The airports authorities use such a

system and several roads authorities around the world use similar ratings systems. Some define three degrees of severity (low, medium and high), some five degrees and others ten degrees. 5-level distress rating system is recommended in these guidelines. This is given in **Table 4.4.**

Table 4.4. Five Level Distress Rating System

Distress Rating	Slab Condition	Severity (Defects) Rating
0	Excellent	Not Discernable
1	Very Good	Minor
2	Good/Average	Moderate
3	Fair	Major
4	Poor	Extreme
5	Very Poor	Unsafe / Unserviceable

4.6.2. Type of repair can be appropriately decided from the distress rating as per details of **Table 4.5.** The techniques for repair can be selected from **Tables 5.1** and **5.2.** The guidance as to the materials suitable for repair is given in Chapter 12. The materials selected should provide the desired performance and durability of 6 to 8 years minimum. Concrete mix proportion characteristics as used in some projects in USA are given in **Appendix-B** for Early Opening to Traffic (EOT) concrete mixes. These may be tried in case of emergency repairs.

4.6.3. The severity level of the defects and distress develop during the contract defect liability period (usually specified as the first year after substantial completion) should generally not exceed degree 2. More time is necessary for distress development under traffic loading, climatic influences and/or unattended maintenance to reach degrees of severity 3 and 4. If degree of severity level 3 was exceeded during the defect liability period of the construction contract, this would probably have to be explained by relevant design and construction shortcomings and rectified under the terms of the contract.

4.6.4. Distresses with degree of severity of 5 (like wide cracks with spalling and/or scaling) exceeding 50% area and/or faulting exceeding 12mm or broken slabs exhibiting rocking effect may be considered for slab replacement or reconstruction, as the case may be.

4.7. Monitoring Performance: Performance or serviceability of the new roads or the roads after repair shall be assessed as per Para 4.2.

Table 4.5. Repair Actions for Different Degrees of Severity of Distress* in Concrete Pavements

S.No.	Type of Distress	Measured Parameter	Degree of Severity	Assessment Rating	Repair Action	
					For the case d < D/2	For the case d > D/2
	CRACKING					
1	Single Discrete Cracks	w = width of crack	0	Nil, not discernible	No Action	Not applicable
	Not intersecting with any joint	L = length of crack	1	w < 0.2 mm, hair cracks		
		d = depth of crack D = depth of slab	2	w = 0.2 - 0.5 mm, discernible from slow-moving car	Seal without delay	Seal. and stitch if L > 1m.
			3	w = 0.5 - 1.5 mm, discernible from fast-moving car		
			4	w = 1.5 - 3.0 mm	Seal, and stitch if L > 1m.	Staple or Dowel Bar Retrofit, FDR for affected potrtion
			5	w > 3 mm.		
2	Single Transverse (or Diagonal) Crack	w = width of crack	0	Nil, not discernible	No Action	
	intersecting with one or more joints	L = length of crack	1	w < 0.2 mm, hair cracks	Route and seal with epoxy	Staple or Dowel Bar Retrofit
		d = depth of crack	2	w = 0.2 - 0.5 mm, discernible from slow vehicle		
		D = depth of slab	3	w = 0.5 - 3.0 mm, discernible from fast vehicle	Route, seal and stitch, if L > 1m.	
			4	w = 3.0 - 6.0 mm	Dowel Bar Retrofit	Full Depth Repair Dismantle and reconstruct affected portion - See Para 5.5 & 9.2
			5	w > 6 mm, usually associated with spalling, and/or slab rocking under traffic	Not Applicable. as it may be full depth	

* 5 level severity rating system : 0 - Not Discernable, 1 - Minor, 2 - Moderate, 3 - Major, 4 - Extreme and 5 - Unsafe/Unserviceable

S.No.	Type of Distress	Measured Parameter	Degree of Severity	Assessment Rating	Repair Action	
					For the case d < D/2	For the case d > D/2
3	Single Longitudinal Crack intersecting with one or more joints	w = width of crack	0	Nil, not discernible	No Action	
		L = length of crack	1	w < 0.5 mm, discernable from slow moving vehicle	Seal with epoxy, if L > 1m	Staple or dowel bar retrofit
		d = depth of crack	2	w = 0.5 - 3.0 mm, discernible from fast vehicle	Route seal and stitch. if L > 1m.	
		D = depth of slab	3	w = 3.0 - 6.0 mm	Staple, if L > 1 m	Partial Depth Repair with stapling
			4	w = 6.0 - 12.0 mm, usually associated with spalling	Not Applicable, as it may be full depth	
			5	w > 12 mm, usually associated with spalling, and/or slab rocking under traffic		Full Depth Repair Dismantle and reconstruct affected portion - See Para 5.6.4
4	Multiple Cracks intersecting with one or more joints or cracks	w = width of crack	0	Nil, not discernible	No Action	
			1	w < 0.2 mm, hair cracks	Seal, and stitch if L > 1m.	
			2	w = 0.2 - 0.5 mm, discernible from slow vehicle		
			3	w = 0.5 - 3.0 mm, discernible from fast vehicle	Full depth repair	Dismantle and reconstruct whole slab
			4	w = 3.0 - 6.0 mm panel broken into 2 or 3 pieces		
			5	w > 6 mm and/or panel broken into more than 4 pieces		Reinstate sub-base, Reconstruct whole slab.

S.No.	Type of Distress	Measured Parameter	Degree of Severity	Assessment Rating	Repair Action	
					For the case d < D/2	For the case d > D/2
5	Corner Break	w = width of crack L = length of crack	0	Nil, not discernible	No Action	
			1	w < 0.5 mm; only 1 corner broken	Seal with low viscosity epoxy to secure broken parts	Seal with epoxy seal with epoxy
			2	w < 1.5 mm; L < 0.6 m, only one corner broken		
			3	w < 1.5 mm; L < 0.6 m, two corners broken	Partial Depth Repair (See Figure 8.3)	Full depth repair
			4	w > 1.5 mm; L > 0.6 m or three corners broken		
			5	three or four corners broken		Reinstate sub-base, and reconstruct the slab.
6	Punchout (Applicable to CRCP only)	w = width of crack L = length (m/m^2)	0	Nil, not discernible		No Action
			1	w < 0.5 mm; L < 3 m/m^2	Not Applicable, as Punchout is a full depth distress	Seal with low viscosity epoxy to secure broken parts
			2	either w > 0.5 mm or L < 3 m/m^2		
			3	w > 1.5 mm and L < 3 m/m^2		
			4	w > 3 mm, L < 3 m/m^2 and deformation		Full depth repair - Cut out and replace damaged area taking care not to damage reinforcement
			5	w > 3 mm, L > 3 m/m^2 and deformation		
	SURFACE DEFECTS				**SHORT TERM**	**LONG TERM**
7	Ravelling or Honeycomb type surface	r = area damaged surface / total surface of slab (%) h = maximum depth of damage	0	Nil, not discernible	No action.	Not Applicable
			1	r < 2 %	Local repair of areas damaged and liable to be damaged.	
			2	r = 2 - 10 %		
			3	r = 10 - 25%	Bonded Inlay, 2 or 3 slabs if affecting	
			4	r = 25 - 50 %		
			5	r > 50% and h > 25 mm	Reconstruct slabs, 4 or more slabs if affecting	

S.No.	Type of Distress	Measured Parameter	Degree of Severity	Assessment Rating	Repair Action For the case d < D/2	Repair Action For the case d > D/2
					SHORT TERM	**LONG TERM**
8	Scaling	r = damaged surface / total surface of slab (%) h = maximum depth of damage	0	Nil, not discernible	No action.	Not Applicable
			1	r < 2 %	Local repair of areas damaged and liable to be damaged.	
			2	r = 2 - 10 %		
			3	r = 10 - 20%	Bonded Inlay	
			4	r = 20 - 30 %		
			5	r > 30 % and h > 25 mm	Reconstruct slab	
9	Polished Surface / Glazing	t = texture depth, sand patch test	0		No action.	Not Applicable
			1	t > 1 mm		
			2	t = 1 - 0.6 mm	Monitor rate of deteriotion	
			3	t = 0.6 - 0.3 mm		
			4	t = 0.3 - 0.1 mm		
			5	t < 0.1 mm	Diamond Grinding if affecting 50% or more slabs in a continuous stretch of minimum 5 km	
10	Popout (Small Hole), Pothole Refer Para 8.4	n = number / m^2 d = diametre h = maximum depth	0	d < 50 mm; h < 25 mm; n < 1 per 5 m^2	No action.	Not Applicable
			1	d = 50 - 100 mm: h < 50 mm; n < 1 per 5 m^2	Partial depth repair 65 mm deep	
			2	d = 50 - 100 mm; h > 50 mm; n < 1 per 5 m^2		
			3	d = 100 - 300 mm; h < 100 mm n < 1 per 5 m^2	Partial depth repair 110mm i.e 10 mm more than the depth of the hole	
			4	d = 100 - 300 mm; h > 100 mm; n < 1 per 5 m^2		
			5	d > 300 mm; h > 100 mm: n > 1 per 5 m^2	Full depth repair	

S.No.	Type of Distress	Measured Parameter	Degree of Severity	Assessment Rating	Repair Action	
					For the case d < D/2	For the case d > D/2
	<u>JOINT DEFECTS</u>				SHORT TERM	LONG TERM
11	Joint Seal Defects	loss or damage	0	Difficult to discern.	No action.	
		L = Length as % total joint length	1	Discernible, L< 25% but of little immediate consequence with regard to ingress of water or trapping incompressible material.	Clean joint, inspect later.	Not Applicable
			3	Notable, L > 25% insufficient protection against ingress of water and trapping incompressible material.	Clean and reapply sealant in selected locations	
			5	Severe; w > 3 mm negligable protection against ingress of water and trapping incompressible material.	Clean, widen and reseal the joint.	
12	Spalling of Joints	w = width on either side of the joint	0	Nil, not discernible	No action.	Not Applicable
			1	w < 10 mm	Apply low viscosity epoxy resin / mortar in cracked portion	
		L = length of spalled portion (as % joint length)	2	w = 10 - 20 mm, L < 25%	do	
			3	w = 20 - 40 mm, L > 25%	Partial Depth Repair	
			4	w = 40 - 80 mm, L > 25%	30 - 50 mm deep. h = w + 20% of w	
			5	w > 80 mm, and L > 25%	50 - 100 mm deep repair. H = w + 20% of w	
13	Faulting (or Stepping) in Cracks or Joints	f = difference of level	0	not discernible, < 1 mm	No action.	No action.
			1	f < 3 mm		
			2	f = 3 - 6 mm	Determine cause and observe. take action for diamond grinding	replace the slab as appropiate
			3	f = 6 - 12 mm	Diamond Grinding	
			4	f = 12 - 18 mm	Raise sunken slab.	replace the slab as appropiate
			5	f > 18 mm	Strengthen subgrade and sub-base by grouting and raising sunken slab	

S.No.	Type of Distress	Measured Parameter	Degree of Severity	Assessment Rating	Repair Action	
					For the case d < D/2	For the case d > D/2
					SHORT TERM	**LONG TERM**
14	Blowup or Buckling	h = vertical displacement from normal profile	0	Nil, not discernible	No action.	Not Applicable
			1	h < 6 mm		
			2	h = 6 - 12 mm	Install Signs to Warn Traffic	
			3	h = 12 - 25 mm		
			4	h > 25 mm	Full Depth Repair	
			5	shattered slabs, ie 4 or more pieces	Replace broken slabs.	
15	Depression	h = negative vertical displacement from normal profile L = length	0	Not discernible. h < 5 mm	No action.	Not Applicable
			1	h = 5 - 15 mm		
			2	h = 15 - 30 mm, Nos < 20% joints	Install Signs to Warn Traffic	
			3	h = 30 - 50 mm		
			4	h > 50 mm or > 20% joints	Strengthen subgrade.	
			5	h > 100 mm	Reinstate pavement at normal level if L < 50 m.	
					SHORT TERM	**LONG TERM**
16	Heave	h = positive vertical displacement from normal profile. L = length	0	Not discernable. h < 5 mm	No action.	scabble
			1	h = 5 - 15 mm	Follow up.	
			2	h = 15 - 30 mm, Nos < 20% joints	Install Signs to Warn Traffic	
			3	h = 30 - 50 mm		
			4	h > 50 mm or > 20% joints	Stabilise subgrade.	
			5	h > 100 mm	Reinstate pavement at normal level if length < 20 m.	
17	Bump	h = vertical displacement from normal profile	0	h < 4 mm	No action.	
			1	h = 4 - 7 mm	Grind, in case of new construction	Construction Limit for New Construction
			3	h = 7 - 15 mm	Grind in case of ongoing maintenance	Replace in case of new construction
			5	h > 15 mm	Full Depth Repair	Full Depth Repair

S.No.	Type of Distress	Measured Parameter	Degree of Severity	Assessment Rating	Repair Action	
					For the case d < D/2	For the case d > D/2
					SHORT TERM	**LONG TERM**
18	Lane to Shoulder Dropoff	f = difference of level	0	Nil, not discernible < 3mm	No action.	
			1	f = 3 - 10 mm	Spot repair of shoulder.	
			2	f = 10 - 25 mm	–do–	
			3	f = 25 - 50 mm	Fill up shoulder	
			4	f = 50 - 75 mm	–do–	For any 100 m stretch
			5	f > 75 mm		Reconstruct shoulder. if affecting 25% or more of stretch
19	**DRAINAGE** Pumping	quantity of fines and water expelled through open joints and cracks	0	not discernible	No Action	
			1 to 2	slight/ occassional Nos < 10%	Repair cracks and joints without delay.	Inspect and repair subdrainage at distressed sections and upstream.
			3 to 4	appreciable / Frequent 10 - 25%	Lift or jack slab.	
		Nos / 100 m stretch	5	abundant, crack development > 25%	Repair distressed pavement sections. Strengthen subgrade and subbase. Replace slab.	
20	Ponding	Ponding on slabs due to blockage of drains	0-2	No discernable problem	No action.	
			3 to 4	Blockges observed in drains, but water flowing	Clean drains etc, Follow up	Action required to stop water damaging foundation
			5	Ponding, accumullation of water observed	–do–	

Adapted from Ref: 3.3 - Committee of State Road Authorities, Pretoria, South Africa, 1990, Standard Nomenclature and Methods for Describing the Condition of Jointed Concrete Pavements, Technical Recommendations for Highways, Draft TRH19:1989, p. 1 – 49. in consultation with CRRI, January 2006 and IRC Rigid Pavement Committee (H-3), March 2008.

PROFORMA 4.1[@]

RIGID PAVEMENT INSPECTION DETAILS

Contract No.

(Project Description)
(Form Km to Km)

Defects Observed During Joint Inpection Conducted on: ____________

by: ____________

To ________ ⇧

Left / ~~Right~~ Side (strike out)

Field Notes:

surface shrinkage cracks, (1mm/SR 2) seal with low viscosity epoxy resin

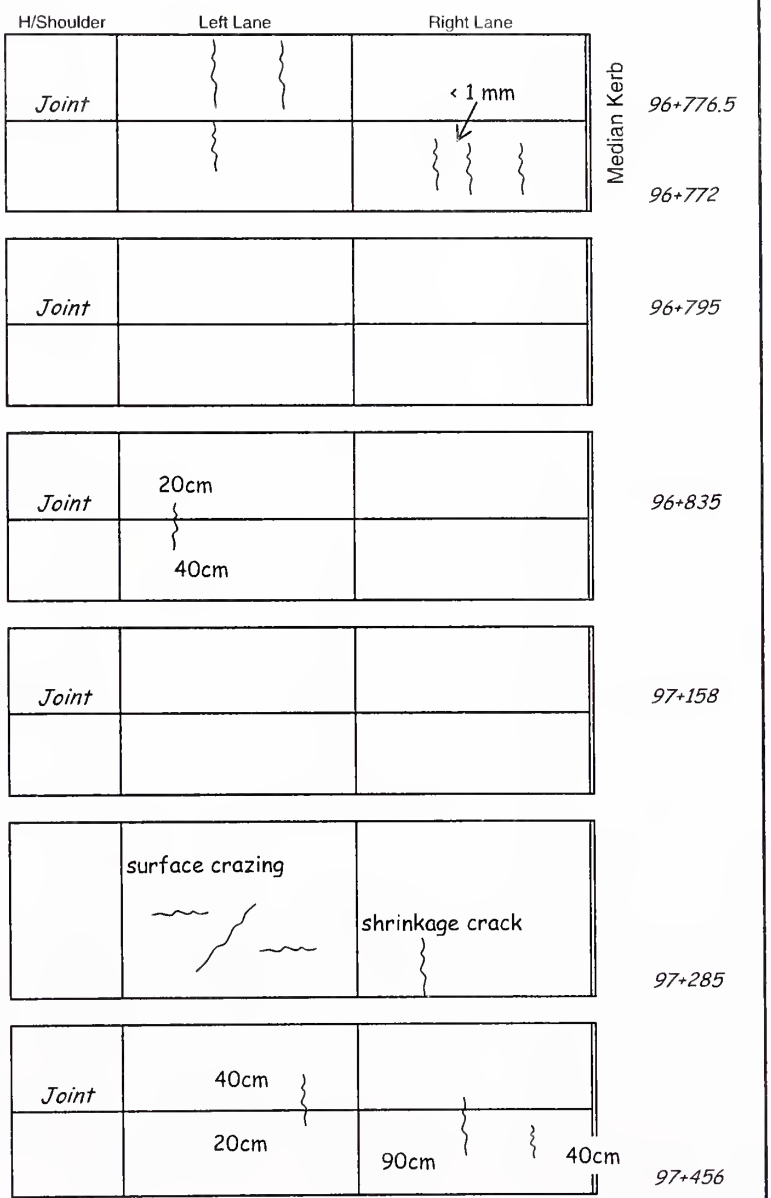
spalling in wheel path

shallow shrinkage crack 1mm

sealant lost/missing

seal shrinkage cracks (1mm/SR 2) with low viscosity epoxy resin

seal with low viscosity epoxy resin



Other Comments:

1. All kerbs and hard shoulder to be cleaned of debris , stones etc
2. Centre line marking for defective, breaking up

Signed by: **For the Engineer**

Date:

Accepted by: **For the Contractor**

Date:

[@]**Sample for guidance from an executed project road**
SR: Severity Rating

PROFORMA-4.2 : LOCATION AND CONDITION OF FULL DEPTH CRACKS & OTHER SERIOUS DEFECTS IN PQC SLABS

Sr. No.	Location		Date Cast	Type of Defect	Severity Rating	Proposed Treatment' (For the case d < D/2)	No. of Slabs Affected	First Reported		Latest Condition Reported			Reasons Given for Defect	Status of Rectification
	New km from	Old Ch from						Date	Crack Width (mm)	Date	Crack Width (mm)	Spalling (mm)		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Sample for Guidance: Left Hand Carriageway														
1	185.830		08.10.02	Longitudinal Crack (New)	1	'Seal with epoxy, if L > 1m	5	06/09/05		06/09/05	0.2-0.3	<5 mm	Consolidation under Parked Trucks	Rectified on 07.06.06
2	196.709		03.03.03	Transverse Crack Near Joint	3	Route and seal with epoxy	3	14.09.04		06/09/05	1-2	<40 mm	Shrinkage	Rectified on 07.01.06
3	202.399			Multiple Cracks at Local Depression	3	Full depth repair	1	20/09/04		01/07/05	<0.5mm	Depression >12 mm	Trafficked during curing Period	Rectified on 17.07.06
4	204.102		24.04.03	Transverse Crack Near Joint	4	Dowel Bar Retrofit	3	20/09/04		01/07/05	3	<20 mm	Trafficked during curing Period	Rectified on 08.10.06
5	204.362		26.04.03	Transverse Crack Near Joint	3	'Route, seal and stitch, if L > 1m.	3	20/09/04		01/07/05	3	<20 mm	Shrinkage	Rectified on 28.09.06
6	206.312		14.05.03	Diagonal Crack	4	Dowel Bar Retrofit	3	21/09/04		01/07/05	0.5	<40 mm	Shrinkage	Rectified on 30.10.06
7	207.802		20.05.03	Transverse Crack	4	Dowel Bar Retrofit	3	21/09/04		29/06/05	0.5	<10 mm	Shrinkage	Replaced whole slab on 05.12.06
8	207.117		21.05.03	Multiple Cracks	5	Full depth repair	2	21/09/04		29/06/05	1	<80 mm	Trafficked during curing Period	Replaced whole slab on 17.12.06
9	207.233		21.05.03	Multiple Cracks at Local Depression	3	Full depth repair	4	21/09/04		29/06/05	0.5	<40 mm	Trafficked during curing Period	Rectified on 17.10.06
10	207.242		21.05.03	Multiple Cracks	4	Full depth repair	1	21/09/04		29/06/05	1	<20 mm	Trafficked during curing Period	Rectified on 17.10.06
11	208.439		13.06.03	Diagonal Cracks	3	'Route, seal and stitch, if L > 1m.	1	21/09/04	1	29/06/05	1	<10 mm	Shrinkage	Rectified on 5.12.06

Sr. No.	Location		Date Cast	Type of Defect	Severity Rating	Proposed Treatment' (For the case d < D/2)	No. of Slabs Affected	First Reported		Latest Condition Reported			Reasons Given for Defect	Status of Rectification
	New km from	Old Ch from						Date	Crack Width (mm)	Date	Crack Width (mm)	Spalling (mm)		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
12	211.220		21.06.03	Transverse Crack Near Joint	4	Dowel Bar Retrofit	3	21/09/04	4	25/06/05	5	<40 mm	Shrinkage	Rectified on 12.09.06
13	211.585		30.06.03	Transverse Crack Middle	4	Dowel Bar Retrofit	3	21/09/04	2	25/06/05	3	<40 mm	Shrinkage	Rectified on 03.09.06
14	212.386		15.07.03	Transverse Crack Near Joint	4	Dowel Bar Retrofit	3	21/09/04	2	25/06/05	3	<20 mm	Shrinkage	Rectified on 10.09.06
15	221.414		31.12.04	Transverse Crack Near Joint	4	Dowel Bar Retrofit	3	22/06/05	2.5	22/06/05	3	<10 mm	Shrinkage	Rectified on 02.08.06
16	223.723		12.01.4	Longitudinal Crack	3	staple	7	22.09.04	4.0	28/07/05	5.0	<80 mm	Shrinkage/Slumping in S/Elevated	Rectified on 07.09.06
17	223.982		13.01.04	Longitudinal Crack (New)	2	Route seal and stitch, if L > 1m.	5	28/07/05	0.3	28/07/05	0.5	<5 mm	Shrinkage	Rectified on 09.09.06
Right Hand Carriageway														
18	220.453		15.07.04	Scalling & Level Fault	5	'Reconstruct slab	4	25.09.04		08/09/05	nil	Scaling >15%	Construction Fault (-25mm)	Rectified ...11.05.06
						Total	53							
						Out of Total	35,600							

No Transverse Crack = 8
No. Longdidunal= 3
No. Multiple/Other= 3
No. Serious Surface Defects= 2

16

percentage of slabs cracked/damaged = (53/35600) x 100 = 0.14 %

Note: (1) The Figs furnished in different columns are to demonstrate how the proforma has to be filled up for different projects. These figures do not pertain to any specific project.
(2) This list excludes fine Cracks and Shallow Plastic Shrinkage Cracking.

Summary Sheet

PERFORMA 4.3

Rigid Pavement **Condition Survey and Distress Rating**

Page: 1 of
Date:
Sign.:

Road: Sample for guidance
Section

LINEAR SKETCH: LHS to ~~RHS~~ to (Strike out which is not applicable)

CHAINAGE (km)	ALIGNMENT: LAYOUT	ALIGNMENT: LONG. ALIGN., gradient (%)	CROSS SECTION height (m), Crossfall (%)	FAULTING / STEPPING	BUMP	BLOWUP / BULKING, SHATTERING	TRANSVERSE CRACK	DIAGONAL CRACK	LONGITUDINAL CRACK	CORNER BREAK	MULTIPLE CRACKS	RAVELLING, SCALING	POPOUT, POTHOLE	JOINT SPALLING	JOINT DAMAGE	LOSS OF SURFACE TEXTURE	SLAB / EDGE PUNCHOUT	PUMPING	Rigid Shoulder (Y/N)	Soft Shoulder (Y/N)	Side Ditch (Y/N)	DRAINAGE CONDITION Good, Poor
29																						G
																				N	Y	P
30																				N	Y	P
30.350														5						N	Y	P
30.372													3									G
30.673													2									G
30.691													2									G
31																						G
31.4495											4											G
31.466									1													G
31.484									1													G
31.646											3											G
32																						G
32.633														4								G
32.654													3									G
32.689													2									G
32.770													2									G
32.914													1									G
33																						G
33.3485							4															G
33.609							3															G
34																						G
34.222													4									G
35																						G
35.559								4														G
35.743									1													G
36																						G
36.049								4														G
36.364											5											G
36.382							4															G
36.472													2									G
36.480											4											P
36.489					4						4											G
36.814							4															G
37																						G
37.618								2														G
37.690							5															G
38																				N	Y	P
38.294									1											N	Y	P
38.814													3							N	Y	P
39				2																N	Y	P
																						G
40																						G
40.355													2									G
40.467							4															G
40.590													3									G
40.831							4															G
41																						G
41.632																						G
Sheet 2																						G

Note: No. 4 indicates severity rating Y = yes N = No G = Good P = Poor

PROFORMA 4.4

Contract No: ________________
(Name of Contract)
(Limits of Contract)

DRAINAGE CONDITION SURVEY DATA

Section / Part – Main Carriageway
Left / Right Side (strike out)

Joint Inspection Conducted on :________________

By :________________________

Designation : ________________

SITE INFORMATION :

1. **Side Drainage** (visual)

Depth to roadside ditch (mm) :	
Condition of roadside ditch satisfactory/poor :	
Type of drainage system present :	
0 = none; 1 = open kuchcha drain; 2 = open pakka drain; 3 = covered drain	
Distance to discharge point (m)	
Remarks:	

2. **Sealant/Lane/Shoulder Joint Integrity (Severity Rating : Reference Table 4.5)**

Sealant Type (Circle)	None - HP - PS - SI – UR - Preformed - Other	
HP = Hot poured ; PS = Polysulphide ; SI = Silicone ; UR = Urethene		
	Paved shoulders (Circle)	**Traffic lanes (Circle)**
Sealant condition (SR)	0 – 1 – 2 - 3 – 4 - 5	0 – 1 – 2 - 3 – 4 - 5
Shoulder condition (SR)	0 – 1 – 2 - 3 – 4 - 5	0 – 1 – 2 - 3 – 4 - 5
SR = Severity rating (see Table 4.4)		

3. **Condition of Vegetation on Embankment** Cut Not Cut

4. **SUMMARY – Overall Assessment of the quality of Drainage**

Poor drainage	
Fair drainage	
Good drainage	
Very good drainage	

5. **OTHER OBSERVATION REMARKS (with sketches, if required) :**

(Adopted from Protocol TP-16, Repair and Rehabilitation of Concrete pavements
Part II Guidelines for Condition Assessment and Evaluation, Report No: FWHA–01-C-000802004, 2004)

5. METHODS FOR REPAIRING CONCRETE PAVEMENTS

5.1. Types of Repair Techniques

Repair techniques can be broadly classified into two categories:

(i) Preventive Techniques
(ii) Corrective Techniques

Preventive techniques are pro-active techniques/activities. These are aimed to slow down or prevent the occurrence of the distress so as to ensure a longer service life of the pavement. Joint and crack resealing are the most commonly applied preventive repair techniques. Full depth repairs are examples of corrective repair activities. There are a number of corrective activities/ repair techniques which perform both the function of corrective as well as preventive repair activities. Diamond grinding, grooving, slab stabilisation, cross-stitching, retrofitting of dowel bars/edge drains and retexturing are some of the activities of the repair techniques which act both as corrective and preventive repair activities.

5.2. Concrete Pavement Restoration Techniques

5.2.1. Concrete Pavement in real situations suffers from one distress or many times with a combination of distresses. There are different techniques to tackle individual distresses. More often, a combination of repair techniques is required to be applied as indicated in **Fig. 5.1**. Preventive techniques in many situations may help the pavement to perform for many years but may not provide a very long-term solution.

5.2.2. Budgetary resources will sometime dictate whether one should go for preventive repair activities to be followed by corrective repair activities or directly to corrective repair activities. The later option will also be dictated by the degree of the severity of distress and urgency of repair. For example, in case of full depth/ deep transverse cracks, resealing can be done early, so that further ingress of water into the pavement is prevented. It can run for some years. Later on to restore the structural integrity of pavement, appropriate corrective repair activities like dowel bar retrofit or full depth repair may be undertaken.

5.2.3. Different activities have to follow a defined sequence. Full depth repairs, dowel bar retrofit or cross-stitching activities must precede the diamond grinding, grooving and resealing of joints. ACPA has suggested a model sequencing pattern which may be considered as a guide in this respect. This sequence is given in **Fig. 5.1.** All locations may not require every repair technique procedure or a combination of procedures. Individual technique/procedure may suffice in many cases.

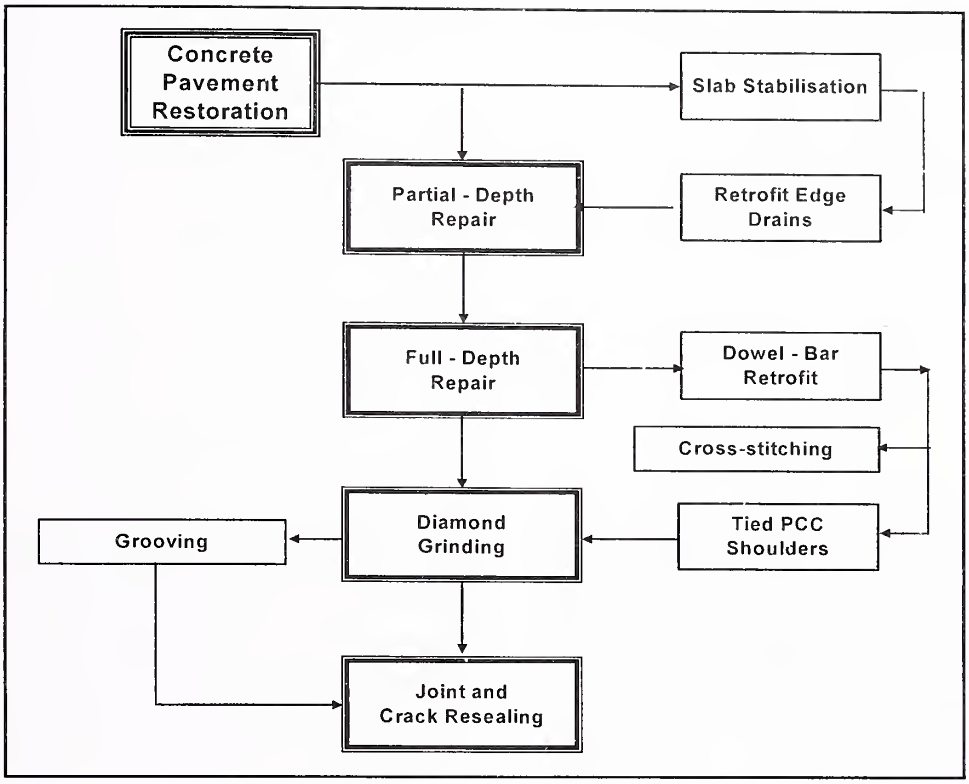


Fig. 5.1. Sequence of Concrete Pavement Restoration Techniques (CPR)
(Published by permission of the American Concrete Pavement Association (ACPA) Copyright, 2008)

5.2.4. The selection and application of a particular repair technique at the proper time is essential for good performance of the concrete pavement. The actual selection of the particular repair technique shall depend on the following:

(1) Type and extent of severity of distress/damage

(2) Causes of distresses to develop

(3) Bearing capacity of subbase and subgrade. Where insufficient bearing capacity is the cause of the distress the subgrade and / or subbase should also be strengthened and/ or stabilized

(4) Volume of traffic and traffic diversion conditions during the work, repair methods that require short work and curing times shall be preferred

(5) Possible reuse of salvaged materials

(6) Responsibility for payment, i.e. repair obligation of the construction agency under defect liability provisions of the contract or payment by the operating agency after defect liability period or handing over whichever is later.

5.3. Timing of Distress Repair

5.3.1. New construction

5.3.1.1. The acceptance criteria for new construction shall be governed by IRC:15-2002 "Standard Specifications and Code of Practice for Construction of Concrete Roads". The acceptance criteria prescribed for cracked concrete slabs in Clause 9.22.7 (IRC:15) is in line with the MoRT&H Specification Clause 602.9.9.4 which states that "The Contractor shall be liable at his expense to replace any concrete damaged as a result of incomplete curing or cracked on a line other than that of a joint". As already stated before, the repair of new concrete pavement, within the defect liability period, shall be governed by the relevant Clauses of the contract. In case where the contract clauses do not provide any specific acceptance criteria for new construction then for such cases it is recommended that acceptance criteria should be that all distresses of low severity (2 or less) vide **Tables 4.4** and **4.5** shall be accepted with minor repair as per the discretion of the Engineer-in-Charge. In case severity is of 4 and 5, it should not be accepted. These could be rectified by reconstruction or by full depth repair, depending upon the extent and severity of damage. For severity 3, the client may apply its discretion depending upon the nature/type of distress. It may, however, be kept in mind that some short term repairs like partial depth repairs etc. are likely to last 6-8 years only and should be avoid in case of new construction.

5.3.2. Old construction

5.3.2.1. For concrete roads in operation, the cost of repair and lane closure are two important considerations in deciding the type of repair to be undertaken. Pavements have their defined service life. Repairs are intended only to ensure that concrete pavements perform till designed service life. The strategies for repair of older pavements could be thus different than those of new pavements. Decision is based on a trade-off between the "cost" of repair and the "remaining" life of the pavement. Road Authorities may decide suitably.

5.3.2.2. Alternative repair strategies for existing pavements are given in the last two columns of Table 4.5. The type of repair to be undertaken, primarily depends upon whether distress is of a structural nature or of non-structural nature. For these guidelines all cracks/distresses are non-structural in nature, when "d < D/2", where "d" is the depth of crack or distress and "D" is the thickness of the slab (PQC). Preventive repair activity in cases, where d < D/2 are recommended. When "d > D/2" i.e. depth of crack/distress is more than half the thickness of the slab, such cracks/distresses are structural in nature. The repair methods recommended are corrective in nature where d > D/2. As already stated before, the repair and maintenance strategies to be followed may involve either short term measure or long term measure or a combination of both, with time spacing to suit the specific condition of distress, availability of fund etc.

5.4. Distress to be Repaired

5.4.1. Visible distressed areas should be repaired according to the standards specified in the contract (if applicable) or as per the **Tables 4.4** and **4.5** whichever sets the more stringent condition.

5.4.2. Generally distress types of low severity (2 or less) may be left with minor repair. Structural distress with severity 4 and 5 as per **Table 4.5** shall receive priority repair, to minimise further damage to the pavement structure with time, to avoid costly repairs/reconstruction. In

such cases, short term repairs may precede the long term repair as per **Table 4.5** to avoid damage extension due to dlay in long term repair.

5.4.3. Some types of distress like depressions, heave, single crack, ravelling, loss of surface texture will only need repair for degrees of severity of 3 or more. Working cracks will be treated with dowel retrofit or with full depth repair depending on degree of severity. Full depth repair are to be undertaken in case of extreme severity.

5.4.4. Single, shallow fine/hair cracks do not require repair. Fine plastic shrinkage cracks are believed to be self healing (autogenous). Fine interconnecting cracks (crazing) should be considered as surface distress and repaired with low viscosity epoxy resins as shown in **Figs. 5.2** and **5.3** before propagating further and developing ravelling.

Fig. 5.2 Plastic Shrinkage Cracks Repaired with Low Viscosity Epoxy

Fig. 5.3 Close Up view of Epoxy Sealing

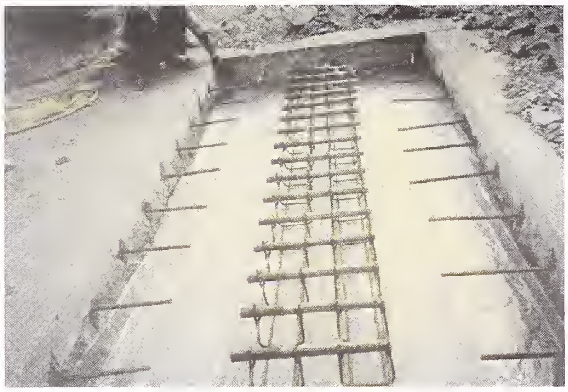
5.4.5. Full depth cracks and damaged joints shall be sealed without delay to minimise ingress of water/incompressibles into the pavement structure. This should be followed with dowel retrofit or full depth repair.

5.4.6. Full depth repair is recommended, if weak concrete is identified or suspected or the pavement had multiple type of distresses such as cracking, ravelling, large pop-outs/potholes and compression failure as blowups etc. Slab areas surrounding the visible distressed area should be sound when struck by a hammer and all areas sounding dull/hollow shall be included in the repair boundries. Weak concrete may extend to neighbouring slabs, and such slabs should also be repaired.

5.4.7. Repair priority should be given to full depth cracks across one or more slabs. The repair of this type of structural distress developing after trafficking for some period often requires sub-grade stabilisation. Repair of full depth transverse cracks always requires new dowel bars to be placed and one new joint constructed as shown in **Fig. 5.4.** The large cracked slab is thus replaced by two smaller slabs with lower curl and warping stresses.

5.4.8 The purpose of joint sealants to prevent ingress of water and incompressible foreign materials. The condition of joint sealant should be watched at regular interval, particularly, before the on-set of monsoon. This should be replaced, when it is worn out, lost adhesion from the groove walls of the joints, hardened badly (oxidised) and has become brittle, has oozed out completely.

a) Full Depth Repair with Drilled-in Dowel Bars (with two new construction joints)



b) Full Depth Repair with Grouted Tie Bar & Dowel Bars Assembly (with one new contraction joint)

Fig. 5.4 Full Depth Repair

5.5. Repair Methodology

5.5.1. Tables 5.1 and **5.2** list a range of techniques and applications for repairing and restoring the integrity of the concrete pavement slab.

Table 5.1. Concrete Pavement Repair Techniques (Preventive Activities)*
(Ref: ACPA Concrete Pavement Restoration Guide)

S.No.	Repair Technique	Application
1.	Crack and Joint resealing with flexible sealant	Used to minimize infiltration of water and incompressible material into joint system
2.	Crack sealing with epoxy resin	Used to seal shallow fine to medium width cracks and prevent concrete breaking out at spalls.
3.	Crack cross stitching	Used to repair low and medium severity longitudinal cracks.
4.	Partial depth repairs	i. Used to repair joint and crack deterioration and surface distress. ii. Used to repair popouts and potholes.

Table 5.2. Concrete Pavement Repair Techniques (Corrective Activities)*
(Ref: ACPA Concrete Pavement Restoration Guide)

S.No.	Repair Technique	Application
1.	Full depth Repairs	Used to repair full depth cracks and joint deterioration. Used to repair punchouts (CRCP)
2.	Slab stabilisation	A specialized technique used to alleviate pumping
3.	Dowel bar retrofit	A specialized technique used to restore load transfer at joints and cracks
4.	Slab lifting or jacking	A specialized technique used to raise sunken slabs by lifting or pressure grouting beneath the panel.
5.	Diamond grinding	A specialized technique used to extend serviceability, improve ride and skid resistance
6.	Diamond Grooving	A specialized technique used to reduce wet weather accidents and prevent hydroplaning

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5.6. Prerequisite Activities for All Types of Repairs

5.6.1. General

All repair techniques discussed in the guidelines will start with the following preparatory activities:

(1) Marking out the areas to be repaired.

(2) Making the temporary working area safe for the workmen from the passing traffic by temporary barricading, signage etc.

(3) Dismantling the affected areas and disposing of the broken concrete in an appropriate way

(4) Any other activities as per the direction of the Engineer-in-Charge.

5.6.2. Marking areas to be repaired

The following activities shall be undertaken for appropriately marking out the area to be repaired.

(a) The total distressed and surrounding areas (to be repaired) are marked on the pavement in rectangular form with sides parallel and perpendicular to the centre line after sounding with a hand hammer, ensuring not less than 50 mm cutting beyond unsound concrete. Rectangular areas simplify saw cutting and concrete removal.

(b) All full depth repairs shall be made the full width of a lane to achieve stable patches and provide adequate room in the pit for dowel hole drill rigs and compaction equipment.

(c) The area to be repaired for a full depth transverse crack shall be a transverse strip. The width will depend on the crack alignment. Odd shaped slabs (L/B > 1.5) and mismatched slabs shall be reinforced with 10 mm dia bars placed at depth of 75 mm from the top and 200 mm C/C both ways.

(d) If the transverse crack is close to a joint (< 1500 mm from the joint) one of the sides of the area to be repaired shall be the nearest joint itself.

(e) The newly cut joint faces shall be scabbled with a chisel or sand blasted to create roughness for better bond between old and new concrete.

(f) Partial depth repairs are usually smaller than 1 m^2. For partial depth repairs if the distance between patches is smaller than 300 mm, the patches are combined in a single large patch.

(g) When two different areas to be repaired or patches are close to each other the repair may be faster and cheaper if the adjacent areas are combined in a large patch.

(h) The criteria for combining adjacent full-depth patches depend on slab thickness and the patch in case of (partial width repair) or lane in case of (full-width repair) width.

5.6.3. Layout for a Repair of Wide Full Width Cracks (d >D/2)/Full Depth Repair (FDR):

The following activities shall be undertaken:

(a) The layout recommended for repair of full width transverse cracks depends on the location of the crack with respect to the joints and free edges as shown in **Fig. 5.5.**

(b) Transverse cracks extending full width of the panel or continuous longitudinal cracks intersecting with formed or sawn joints are not acceptable in new construction i.e. before "Taking Over" from the contractor by the client as per IRC:15 and MoRT&H Specifications for Road and Bridge Works. However, these may be provided with tie or dowel bars as part of a short term maintenance strategy after "Taking Over". Dowel bars shall be used in such conditions where widening of the crack may occur.

(c) For cracks at a distance of more than 1.5 m from the next transverse joint, slots for retrofitting of dowel bars shall be cut and the dowel bars placed at distances of 250 – 300 mm before the crack is widened and sealed. This is a stop gap arrangement. The permanent treatment would be to make a full slab replacement or cutting out the affected part of slab by full depth cutting. Holes are made for tie bars and additional contraction joint is made by providing dowel bars (**See Fig. 5.5**).

(d) For cracks located at short distances from joints (ie. at less than 1.5 m) the strip of slab between the crack and the joint shall be cut to a regular rectangular shape and removed. The condition of the existing dowel bars shall be checked and new holes for new tie bars shall be drilled in the opposite sawn cut face. These shall be thoroughly cleaned with compressed jet air and filled with a thick epoxy. The tie bar shall be inserted by hammer imparting light thuds at the head of the tie bar so that the epoxy oozes out insuring complete bond between the circular wall of the hole and ribbed surface of the tie bars. The epoxy shall be allowed to cure for a minimum period of four hour.

(e) If the slab displays two or more than two full width cracks complete slab reconstruction shall be considered or repair may be carried out as per the advice of Engineer-in-Charge.

(f) The concrete faces with tie bars shall be scabbled/sandblasted to give a rough key to the new concrete. The pit shall be filled with the approved concrete mix, compacted and textured to match the surrounding slabs. Before concreting the bottom and sides of the pit are kept wet for few hours (not less than 4 hours). The condition of surface should be Saturated Surface Dry (SSD). Some agencies use cement: sand 1:1 slurry with w/c ratio not more than 0.62 to coat the sides and bottom of pit(the slurry should not be allowed to dry). While pouring fresh concrete, it shall be placed in central portion of the pit first and then worked towards edges ensuring complete vibrations including in the corners.

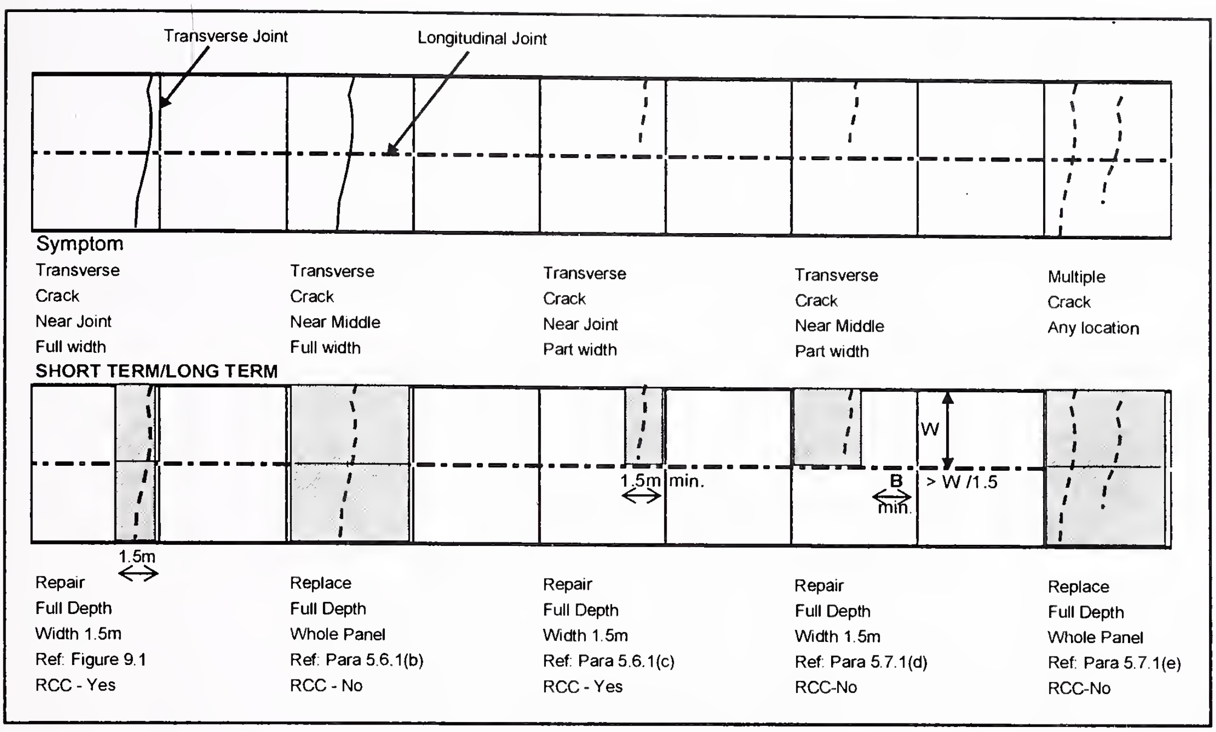


Fig. 5.5. Recommended Layout for Transverse Cracks Repairs – Plan View

5.6.4. Layout for Repair of Deep Longitudinal Cracks

The layout recommended for repair of deep longitudinal cracks again depends on the location of the crack with respect to the joints and free edges as per **Fig. 5.6.** Stitching or partial depth patching may be tried depending on the severity of the defect and behaviour of the repair under traffic. Continuous longitudinal cracks intersecting with formed or sawn joints are again not acceptable in new construction and all the slabs affected should be replaced prior to "Taking Over" or repair may be carried out as per advice of Engineer-in-Charge.

5.7. Cutting and Removing Debris

(a) Saw cutting and chipping are the operations required to remove the unsound concrete within the marked area and leaving a rectangular patch pit of uniform depth.

(b) The sidewalls of the pit to be cut are usually specified as vertical and the vertical sections of the pit are rectangular.

(c) Special care shall be taken not to damage the adjoining panels when chipping concrete for full-depth patches. For this purpose chipping of the slab concrete shall only take place after making a cut at a distance of 50 mm into the sound panels. Within this area additional saw cuts may be made to expedite removal of slab pieces as per **Fig. 5.7.** After the concrete inside the delineated area has been chipped and removed the remaining strip between cuts and joints can be safely removed.

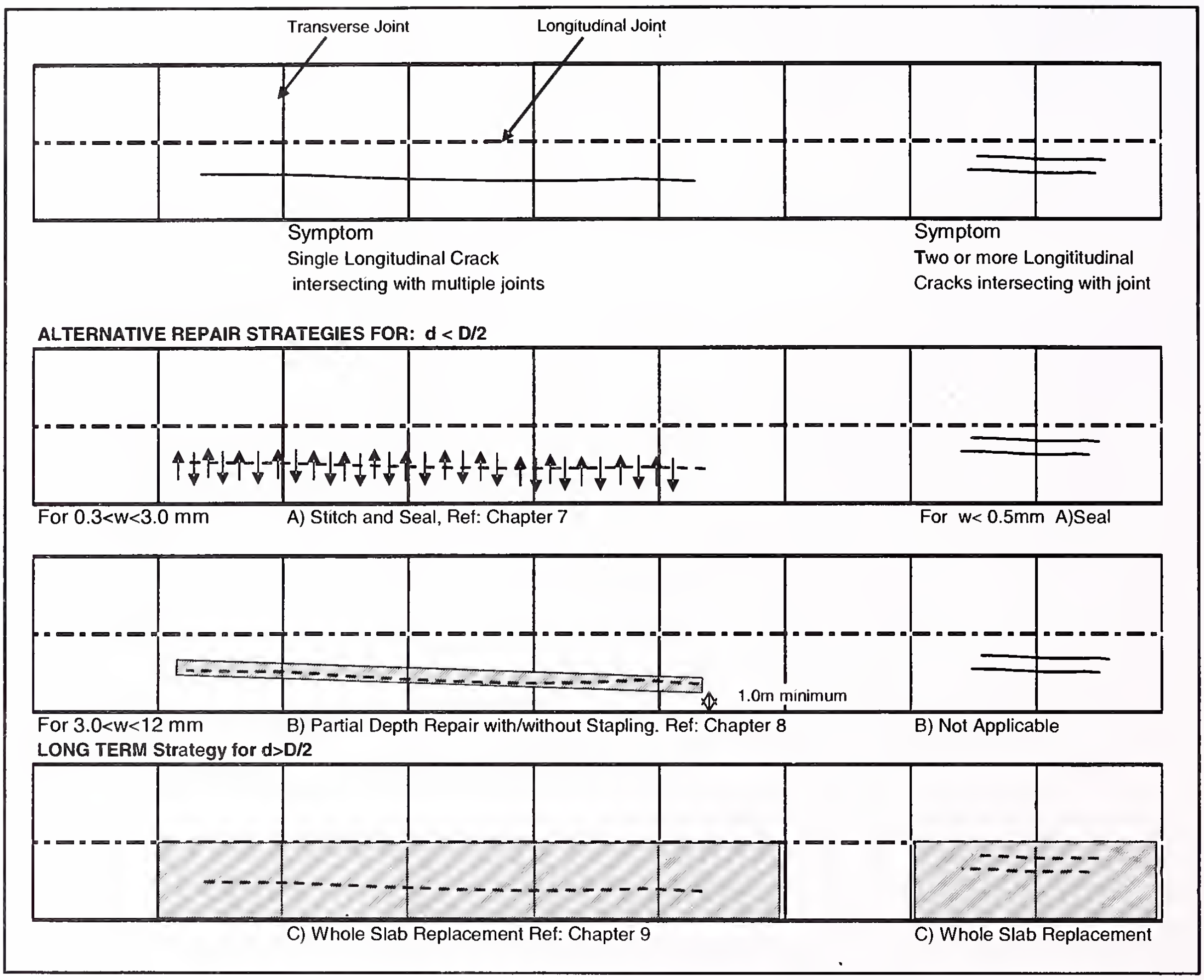


Fig. 5.6. Recommended Layout for Transverse Cracks Repairs – Plan View

(a) Saw cutting

(b) Breaking Out by Jack Hammer after making two parallel saw cuts

Fig. 5.7. Saw Cut and Break Procedure Illustrated

(d) If the repair extends up to the slab joint insert a piece of oiled shuttering ply in the adjacent joint(s) to avoid percolation of patching material in the joint.

5.8. Saw Cutting and Lifting Procedure for Full Depth Repair and Whole Slab Replacement :

It comprises of the following procedure:-

(a) The marked area is sawn with diamond blade saw in pieces or whole according to availability of crane or other machinery to lift and remove slab pieces as shown in **Fig. 5.8.**

(b) The remaining pieces of slab left over tie bars and dowel bars is broken in such a way that the concrete in the adjacent good slab is not damaged.

(c) Lifting the whole piece of concrete imparts no damage to the sub-base and is readily done. This method requires less labour than breaking the concrete before removing. Different types of equipment can be used to lift the slab or slab portion by means of a chain connected to lift pins: torque claw attachments for front-end loaders, forklift devices and vertical bridges.

(a) Saw and Break Procedure

(b) Saw and Lift Procedure

Fig 5.8. Saw Cut and Lift Procedure Illustrated

5.9. Work Safety and Traffic Diversion

(a) Before the repair work is carried out, the proper traffic diversion shall be planned and implemented in consultation with the Engineer-in-Charge having full regard to the statutory and contractual provisions for safety.

(b) All signals required for traffic diversion and work safety shall be brought to the site and placed at appropriate sections and distances.

(c) When the work is finished and curing completed all debris and traffic control measures shall be removed and normal traffic conditions restored (For details refer **Chapter 15).**

5.10. Disposal of Dismantled Materials

The concrete dismantled during partial depth repair/ full depth repair/ grinding and grooving etc. shall be suitably disposed off as provided in the contract. These guidelines, however, recommend the following steps for the disposal of dismantled materials:

(a) the concrete should be broken to sizes not greater than 0.02 cum and stacked neatly in the ROW (Right of Way) for later reuse or till it is finally disposed off as per contract.

(b) The chunks should be sorted into range of sizes, with larger chunks (less than 0.02 cum in size) broken further by hand or put in the crusher to break them into smaller size particles so they can be reused as an aggregate for non structural purpose. For example it can be:

   (i) Used in GSB by mixing 20% - 25% of the broken particles (75 mm down) with new material if required after satisfying necessary laboratory tests for the layer concerned.

   (ii) Mixed with gravel/moorum mixture for protecting the earthen shoulder after satisfying necessary laboratory tests.

   (iii) Used in the Dry Lean Concrete (DLC) or foundation levelling course (M-10) after satisfying necessary laboratory tests.

   (iv) Used for the mechanical stabilisation of weak soils after satisfying necessary laboratory tests.

(c) Any unused material maybe auctioned or disposed off according to the environmental rules and instructions of the Engineer-in-Charge.

6. CRACK SEALING AND JOINT RESEALING

6.1. General

6.1.1. This is a frequently applied preventive repair technique normally used as a part of periodic maintenance. If the edges of the crack are severely broken (spalled) the slab should be cut 30 mm deep on both sides of the crack at a distance of 10-12 mm each side. The concrete is removed between the cuts and the crack is filled with a fine epoxy resin mortar then clean and apply prime coat of epoxy resin on the sides as well as on the bottom of the patch after the cuts have dried as shown in **Fig. 6.1 (b).** Crack widening and sealing follows the same work procedure as joint grooving and resealing.

6.1.2. Different methods to seal and patch cracks are illustrated in **Fig. 6.1** and are briefly described below:

(a) **Gravity Application of Low Viscosity Epoxy Eesin:** cracked area is first cleaned by blasting with air. A low viscosity, free flowing, fast curing epoxy resin can be applied from a plastic beaker or from end of a nail by gravity into cracks 0.5 mm - 5 mm wide to secure broken concrete pieces together to prevent it from breaking out. Epoxy resin to be used should be with viscosity in range 300 centipoise @ 20°C-110 centipoise @ 30°C. See **Fig 6.1 (a).**

(b) **Epoxy Resin Injection:** Resin injection can be used to make structural repair of deep cracks, particularly corner breaks, by following the method described in MoRT&H Specification. The resin is injected at high pressure in previously bored holes along the crack. The resin fills the crack and sometimes the interface of the slab with the sub-base if the pressure is maintained for a long period. The broken slab is thus secured together and better supported by the sub-base. See **Figs 6.1 (b) and 6.1 (c).** Care has to be taken not to fill the adjoining construction joints resin.

(c) **Retaining as a "Working Crack" with Elastomeric Sealant:** Suitable as a short term measure at cracks which do not display faulting and rocking under the traffic load. Route along the crack to provide a uniform groove and apply an elastomeric sealant. The life expectancy will generally depend on the volume of the traffic and the condition of the sub-base.

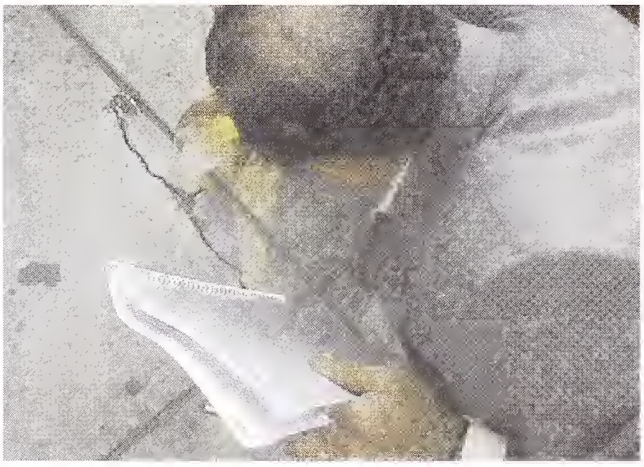
6.1.3. Overfilling of cracks or joints should be avoided as the residue will be struck by the tyres of the vehicle which often leads to uproot of entire sealant.

6.1.4. Crack sealing between untied/asphalt shoulder shall be filled with a mixture of emulsion rejuvenator and topped off with sand.

6.1.5. Low viscosity epoxy shall also be poured along the boundaries of the patch thus repaired with epoxy/epoxy mortar/epoxy concrete. Dry fine sand shall be spread over these. Different methods to seal/cracks is given in **Fig. 6.1.**

Clean affected area

Measure correct proportions of resins and hardener



Pouring Low Viscosity Epoxy Resin

a) Treatment of Shallow Spalling at Joints by Gravity Sealing with low viscosity epoxy

b) Routing Groove in Plastic Shrinkage Crack and Sealing with Epoxy Mortar (1:3)

c) Sealing wide Cracks by Epoxy Injection

Fig 6.1. Treatment of Cracks with Epoxy Resin Formulations

6.2. Joint Resealing

6.2.1. Over time all types of joint sealants suffer distress. They lose flexibility, bond to the walls of the joint groove and may crack. The sealant may be subject to very harsh conditions. Accordingly the material selected for joint sealing, shall be capable of:

(i) Withstanding horizontal extension and compression and vertical shear;

(ii) Withstanding climate effects such as weathering by UV rays in some sealants, extreme temperatures and moisture;

(iii) Resisting penetration by stones and sand at temperatures:

(iv) Maintaining strong bond to concrete sidewalls at specified temperatures.

6.2.2. Joints shall be resealed as necessary to minimise both infiltration of runoff water in the pavement structure and ingress of incompressible material in the joint groove as shown in **Figs. 6.2 & 6.3.**

6.2.3. The commonly used sealant materials applicable specifications, the design extension, shape factor and relative price are listed in Table 12.6 of Chapter 12. For maintenance work the same type of sealant shall be used and preferably from the same manufacturer if performing well. The manufacturers specifications shall be consulted to check the required maximum allowable service extension that the sealant material can sustain without damage and if a primer is required to improve the bond between sealant and concrete.

6.2.4. The joint groove dimensions should be selected after determination of the expected joint movement resulting from temperature changes. The shape factor is defined as the ratio of depth to width of sealant in the joint groove. Too narrow grooves may originate extension failure of the sealant or loss of bond with the groove walls. Manufacturers of silicone sealants recommend a minimum thickness of 6 mm and a maximum thickness of 13 mm because wider joints are prone to spalling.

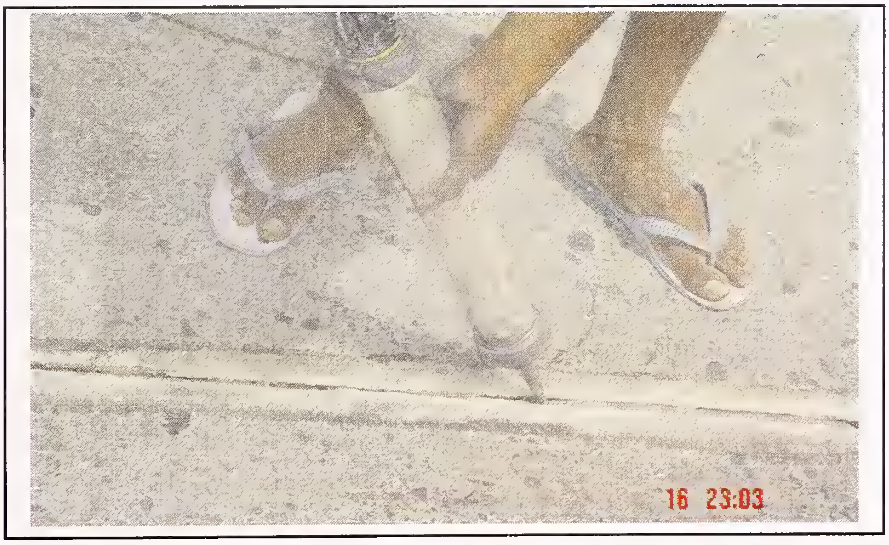


Fig. 6.2. Joint Resealing

6.2.5. The groove saw cut depth must provide for the sealant depth, the compressed backer rod thickness, the depth that the sealant surface is to be recessed and extra depth to account for variability of the saw depth as shown in **Fig. 6.3.**

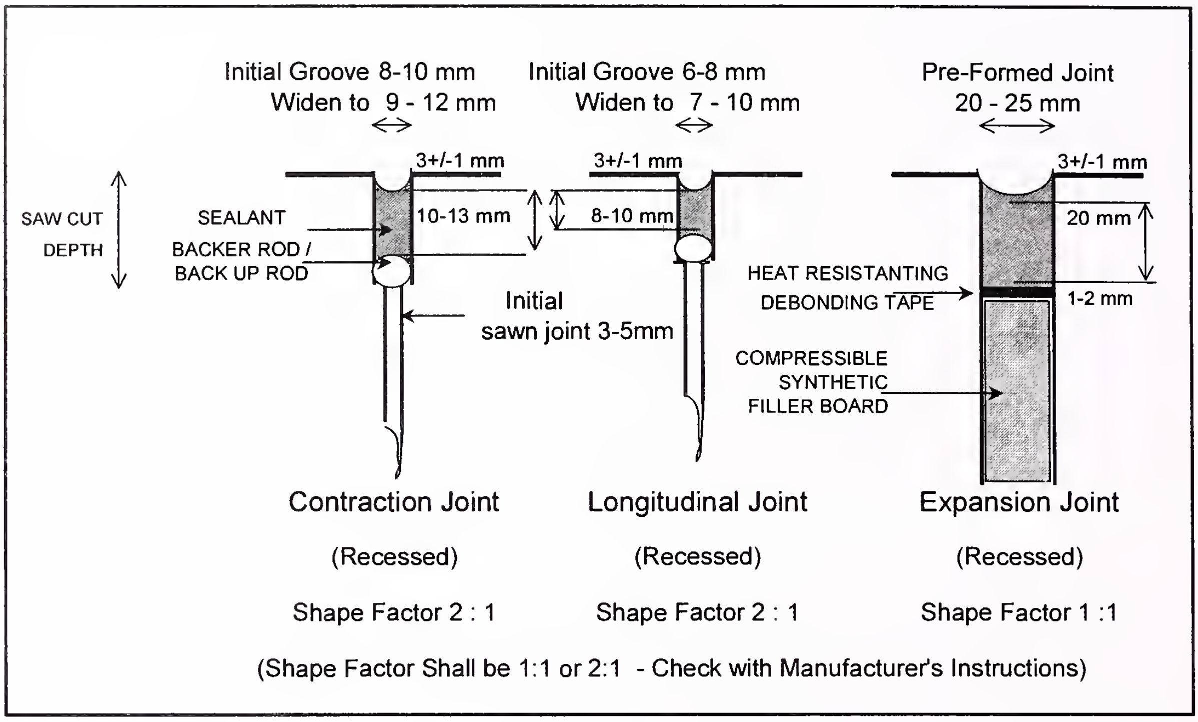


Fig. 6.3. Typical Detail of Field Moulded Joint Sealants (Source: Fig. 4 IRC:57-2006)

6.2.6. The service life of joints depends on the care taken to prepare the joint and install the sealant. The service life of joint seals also varies with the type of sealant. A typical hot-pour sealant provides an average of 3 to 5 years of life after proper installation. Some low-modulus or PVC and coal tars can perform well past 8 years. Polysulphide sealants perform well for up to 5 to 7 years according to experience on the National Highway Development Project (NHDP) to date. Silicone sealants perform well for periods exceeding 8 to 10 years. In Australia and the USA, where pavements are well maintained in good/clean condition, silicone seals have given good performance up to 20 years. Compression seals may provide service for periods often exceeding 15 years and sometimes 20 years in access controlled highways in developed countries. Further study of the issues of adhesion, temperature, UV radiation and presentive themedy against theft is required in India. But the most important condition is that the joint be clean and dry when reapplying the sealant (adhesive in case of compression seals). Also, some materials are unsuitable for bonding to fresh concrete and so technical advice should be sought from sealant manufacturers regarding the recommended minimum concrete age at the time of installation.

6.2.7. Joints sealants should be replaced periodically when they are defective or reach the end of their service life and do not prevent ingress of water any more. Simply pouring new sealant in the old joint will not restore the latter. The old joint material shall be removed, the joint groove cleaned and the new joint material properly placed. This work must be performed under dry conditions and preferably scheduled in the warmer months of the year.

6.2.8. When the joints are spalled compression seals should not be used before its proper repair because they would tend to twist or move up and down in the joint at locations where the joint walls are not vertical and uniformly smooth.

6.2.9. The sealant is applied after insertion of a backer rod in the groove. Backer rod keeps off the fluid sealant from sinking in the groove and bonding to the bottom of the groove. They shall be flexible, compressible, undergo no shrinkage, repel water and not react with the sealant. The rod diameter should be at least 25% larger than the joint width.

6.3. Method for Repairing the Flexible Joint Sealant

(1) **Select the material and method of applying the liquid sealant,** taking necessary approval from the Engineer-in-Charge.

(2) Materials from the compression joints can be removed manually without leaving much material on the groove walls. Materials from the other types of joints can be also pulled by hand after cutting by running a knife blade along the faces of the wall or running a saw cutting machine with worn/used blades or by ploughing. Most sealants can be very effectively removed by ploughing (raking). A small joint plough (small tractor pulling a hard steel cutter/rake slightly narrower than the joint width) can remove the old sealant material without causing damage to the joint edges. V-shaped plough/ rakes should not be used. Rectangular plough/rakes cause very little damage to the joint faces. The plough/rake should pass at least twice cleaning one joint face during the first pass and the other joint face during the second pass. Ploughing should remove at least 95% of the old sealant material.

(3) **Joint materials are removed and disposed properly.** Some materials may require hazardous or specialised waste disposal methods.

(4) Width of groove and shape of the groove is improved for the new material as per provision of IRC-57. The groove shall be shaped by sawing with a diamond blade. This is an efficient method for ensuring complete removal of old sealant. Reshaping the old groove may be required for improving or modifying the shape factor and can be done by cutting with dry or wet diamond blades. In many cases blades are ganged side by side on the blade arbour with a metal spacer to allow the saw to reface both joints to a uniform width in one pass. However, some sticky sealants such as PVC and coal tar can clog the diamond blade. The refacing of the groove shall be kept to an absolute minimum in order to keep the joint groove from becoming too wide, which may lead to risk of extra damage and spalling at the joint.

(5) **Edges of the joint groove are chamfered** to improve the durability of the sealant and the profile. Minor spalls along the joint faces do not inhibit performance of most sealants but some patching may be needed for larger spalls. These shall be patched before proceeding with groove cleaning.

(6) **The groove faces of the joint are cleaned thoroughly.** This is the most important task of joint sealing. Groove faces require a thorough cleaning to ensure sealant adhesion and long term good performance. Dirt, dust or traces of the old joint material shall not remain on the joint faces after cleaning. Joints wider than 10 mm are easy to clean. Cleaning of narrow joints of 6 mm width or less is very difficult and shall be carefully performed.

Note: Using chemical solvents for cleaning is not allowed because they can leave contaminants in the pores of the joint faces that will inhibit bonding of the new sealant. Proper cleaning combining mechanical action with water flushing is required.

(7) The saw slurry and any cleaning chemical residues shall be washed away immediately after sawing in a single direction.

(8) **The groove faces are sandblasted** one by one when the joint is dry. The sandblast is done by holding nozzle close to the surface at an angle with the top of the face. Sandblast removes residues of the old sealant and provides surface texture to improve sealant adhesion. Alternatively when compression seals are to be used the sidewalls may be prepared by grinding or wire brushing.

(9) **The joint and pavement surface is air blasted** to remove any remaining sand and dust, ensuring the compressor is blasting clean air without oil contamination prior to air blasting. If not, an oil and moisture filter is required or the insertion of oil in the air by the compressor shall be discontinued.

(10) **The surrounding pavement is kept clean** by use of a vacuum sweeper or broom.

(11) **The compressible backer rod is installed** to give the correct shape and depth to the sealant. The backer rod material shall be compatible with the liquid sealant and have a diameter about 25% larger than the groove width. Backer rods shall be forced into the groove joint uniformly to the desired depth. Many methods have been used including poking in with a screwdriver that may damage the surface of the rod and automated equipment. The best tool is the steel roller with two lateral wheels supported by the pavement surface and a central insertion wheel that can be changed to match different depths. Good practice is to roll the insertion wheel over the backer rod twice in opposite directions.

(12) **Groove sidewalls are checked** that these are free of dust and dirt before pumping the sealant. The joint should be cleaned again if any traces of contamination are found.

(13) **The primer is applied** to the dry side walls of the groove according to the recommendations of the manufacturer. The durability of priming depends on climatic conditions.

(14) **Installation** requirements are different for each type of sealant. Recommendations from the concerned/selected manufacturer should be followed. Manufacturers also

provide mobile equipment to melt and pump the hot sealant into pavement joints and also to apply cold applied sealant material.

(15) **The liquid joint sealant is installed** at the proper temperature recommended by the manufacturer. When the sealant is at the right temperature about 250 ml (1/4 litre) of cold sealant should be discarded from the pumping unit hoses and nozzle before installation begins. The nozzle shall be introduced in the groove to fill the sealant from bottom and reduce chances of trapping air. Instead of pushing the nozzle, the operator shall draw it towards himself to achieve a more uniform cross section and less voids. The groove shall not be filled to the top, The sealant surface shall be recessed 3 + 1 mm from the pavement surface. Tool the sealant with a wooden spatula after 10 minutes and then apply more sealant, if needed.

Note: The nozzle shall be sized to match the groove width and no moisture should be allowed in the latter.

(16) Low-modulus silicone sealants are not self-levelling and require tooling within 10 minutes of installation before they begin to "break /cure" and form a skin. A tool or a backer rod strip is drawn over the fresh sealant to force it in contact with the sidewalls at the top of the groove and produce a concave shape.

(17) Moist grooves shall be previously first dried to avoid boiling of water in contact with the liquid sealant which may inhibit adherence.

(18) When transverse joints are sealed with silicone and longitudinal joints are sealed with hot-pour sealants, silicone shall be applied first because it is viscous and will only slightly penetrate the longitudinal joints.

(19) Finally check sealant adhesion to the sidewalls by pushing down a knife blade along the groove sidewalls.

(20) Check the curing of silicone sealant after 2 to 3 weeks by removing a small 50 mm long specimen of sealant and stretching about 50% for 10 seconds. A fairly fast and uniform relaxation of the specimen indicates adequate curing. Slow rebound and curling indicates differential curing. To take advantage of good adherence of the silicone material to itself use the same brand of sealant to repair the gap from which the sealant specimen was cut.

6.4. Compression Seals

6.4.1. Defects in compression seals generally comprises:

(a) failure of the bond with the groove walls
(b) pulling out/theft by vandals

6.4.2. Reinstatement of compression seals comprises of the following:-

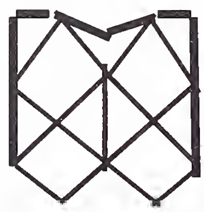
(1) The joint side walls are inspected for ravelling, spalling and other irregularities that could reduce the seal's lateral pressure and originate seal extrusion or popping out from the joint. Repair damaged sections before installation of the compression seal.

(2) Any burrs along the sawed joint are removed by dragging a blunt, pointed tool along sawed joints. This removes sharp edges which if left untreated may make the seal installation difficult. A mechanised wire brush can also be used for this purpose. This type of operation shall be done only where needed and before cleaning the groove.

(3) Lubricant/adhesive is applied to the seal edges and/or groove sidewalls.

(4) The compression seal as shown in **Fig. 6.4 (a)** is installed taking care not to stretch the seal more than 2-3% during installation. Stretching by more than 5% could be detrimental and later on may cause sealant to break into pieces. Special attention shall also be paid to avoid twisting and nicking in addition to stretching. To monitor sealant stretching lay a length of sealant parallel to the joint and cut a piece of seal with the same length. The piece of seal is extracted and its length is measured after relaxation, stretch in percent is calculated.

(5) Improper adhesive may cause failure of compression seal as shown in **Fig. 6.4 (b).**



a) Typical cross-section of Compression Seal

b) Loosening of Compression seal

Fig. 6.4. Compression Seals

6.4.3. The **Fig. 6.5 (a)** shows that the liquid sealant has failed in adhesion and is missing in parts. This gap gets filled up with refuse, dust, aggregates and all other filthy materials. If movement is restricted or materials enter the joints, excessive stress develop, resulting in development of defects and plying of traffic further enhance the problem. Due to these unfilled open joints, potholes may start developing leading to the spalling of the transverse joints and cracks at joints. **Figs 6.5 (b)** and **6.5 (c)** show sand blasting the groove walls and subsequent clearing with compressed air jet. **Fig. 6.6** shows further pictures in sequence of the method for repair of joint sealants.

a) The Liquid Sealant Adhesion Failure

b) Sand blasting the groove after raking out the sealant residue and rubbish from the joint.

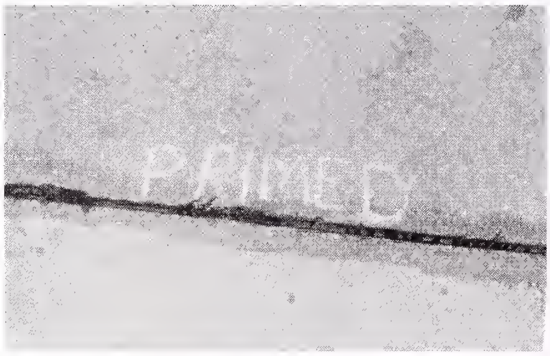
c) Compressed Air used to clean

Fig. 6.5. Preparation for Reinstatement of PQC Joint Sealants

a) Air cleaning

b) Placing the backing rod

Fig. 6.6. Priming and Reinstallation of PQC Joint Sealant



c) Priming the groove surface as per manufacturers instructions

d) Mixing

e) pouring the gun grade cold sealant

f) Tooling the sealant to remove all air bubbles

Fig 6.6. Priming and Reinstallation of PQC Joint Sealant

7. CRACK STITCHING (CROSS-STITCHING)

7.1. General

7.1.1. Crack stitching with inclined tie bars (cross-stitching) or U-bars (stapling) may be used for cracks in reasonably good condition in order to arrest movement of slabs and slab pieces. Stitching maintains aggregate interlock, prevents the crack from vertical and horizontal movement or widening and provides added reinforcement and strength. Table 4.5 shall be referred to for selecting suitable cases for this type of repair.

7.1.2. Cross-stitching serves the same purpose as tie bars and bent tie bars (stapling) but requires less surface disruption than do installing tie bars.

7.1.3. Cross-Stitching shall not be used as an alternative for treating cracks that are severely deteriorated/spalled or there is movement of broken parts. It is normally used for the treatment of narrow longitudinal and diagonal cracks which do not display spalling or other types of distress. Full depth transverse cracks which have assumed the role of an adjacent joint should not be stitched. Stitching will not allow joint movement (open and closure), so a new crack is likely to develop near a stitched working crack or the concrete will spall over the reinforcing bars and along the crack. In such cases dowel bar retrofit, full depth repair or whole slab replacement should be used depending on alignment and position of the crack.

7.2. Methodology for Cross-Stitching

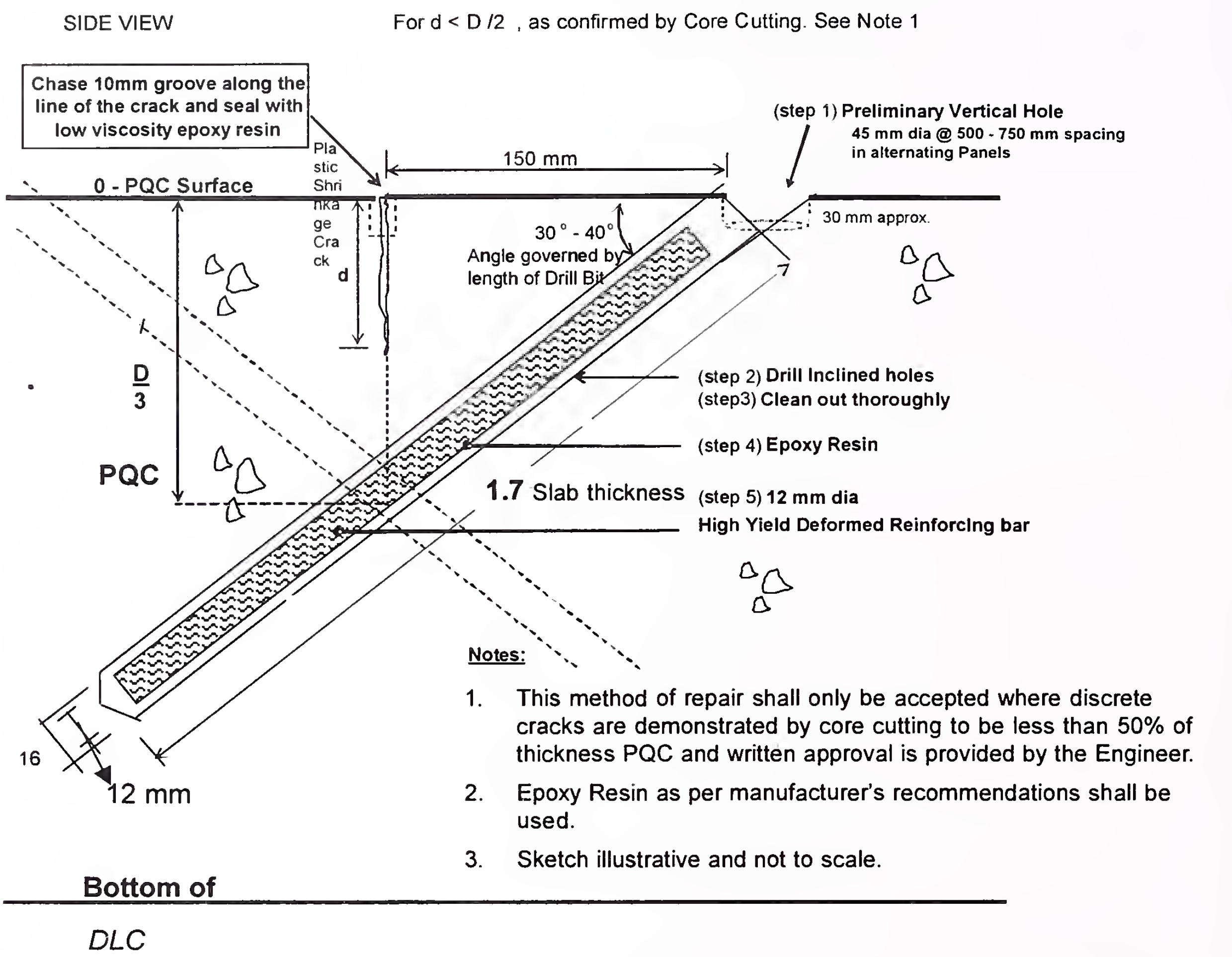
The cross-stitching procedure is illustrated in **Fig. 7.1.** The same is as follows:

(1) Preliminary vertical holes (diameter Ø = 45 mm), 30 mm deep are drilled in an alternating pattern at 500 mm - 750 mm spacing apart, where the inclined hole starts to facilitate its drilling.

(2) Alternate inclined holes (Ø = 16 mm) about 30° to 40° from the slab surface normal to the line of the crack are drilled; the length of the holes shall be = 1.7 times slab thickness. The holes should be spaced as for (1) above and alternate from each side of the crack. Whilst a 500 spacing is generally recommended, a 750 mm spacing is adequate for light traffic and lightly loaded inner highway lanes. For heavy traffic and outer lanes, a spacing of 500 mm C.T.C. is preferred. The dimensions and spacing also depend on the slab thickness in a similar manner as dowel bars.

(3) The holes are cleaned thoroughly using oil-free compressed air;

(4) The hole is filled with epoxy resin in enough quantity for the bar to be completely coated when inserted in the hole;



Notes:

1. This method of repair shall only be accepted where discrete cracks are demonstrated by core cutting to be less than 50% of thickness PQC and written approval is provided by the Engineer.
2. Epoxy Resin as per manufacturer's recommendations shall be used.
3. Sketch illustrative and not to scale.

Fig 7.1. Typical Arrangement for Cross-stitching with 12 mm. dia Straight bar

(5) A high yield deformed reinforcing bar (Ø = 12 mm) is placed conforming with IS: 1786 in every hole.

(6) A groove shall be made along the line of cracks displaying spalling and filled with a low viscosity resin or fine epoxy mortar as appropriate as per Para 6.1.1.

7.3. Methodology for Stapling

The "stapling" procedure illustrated in **Fig. 7.2** is as follows:

Step 1 Mark the position of vertical holes of dia 30 mm at a distance of 228 mm from the crack at a spacing of 600 mm centre to centre

Step 2 Drill the holes 30 mm dia to a maximum depth of D/2

Step 3 Cut the slit of 30 mm widths of a depth of 50 mm less than D/2

Step 4 Remove debris and clean the holes and slit

Step 5 Roughen the sides of holes and slits by sand blasting/sand paper

Step 6 Insert tor steel bars (Fe 415) (**Fig. 7.3**).

Step 7 Fill the hole and slit with epoxy mortar (1:3-epoxy:sand) upto 10 mm above the top surface of steel bar

Step 8 Above this level, nonshrinkable concrete or any other equivalent material may be filled up to the top level of PQC.

Step 9 Fill the sides of the groove with low viscosity epoxy.

Fig. 7.2. Drilling the Inclined Holes with Angle Template

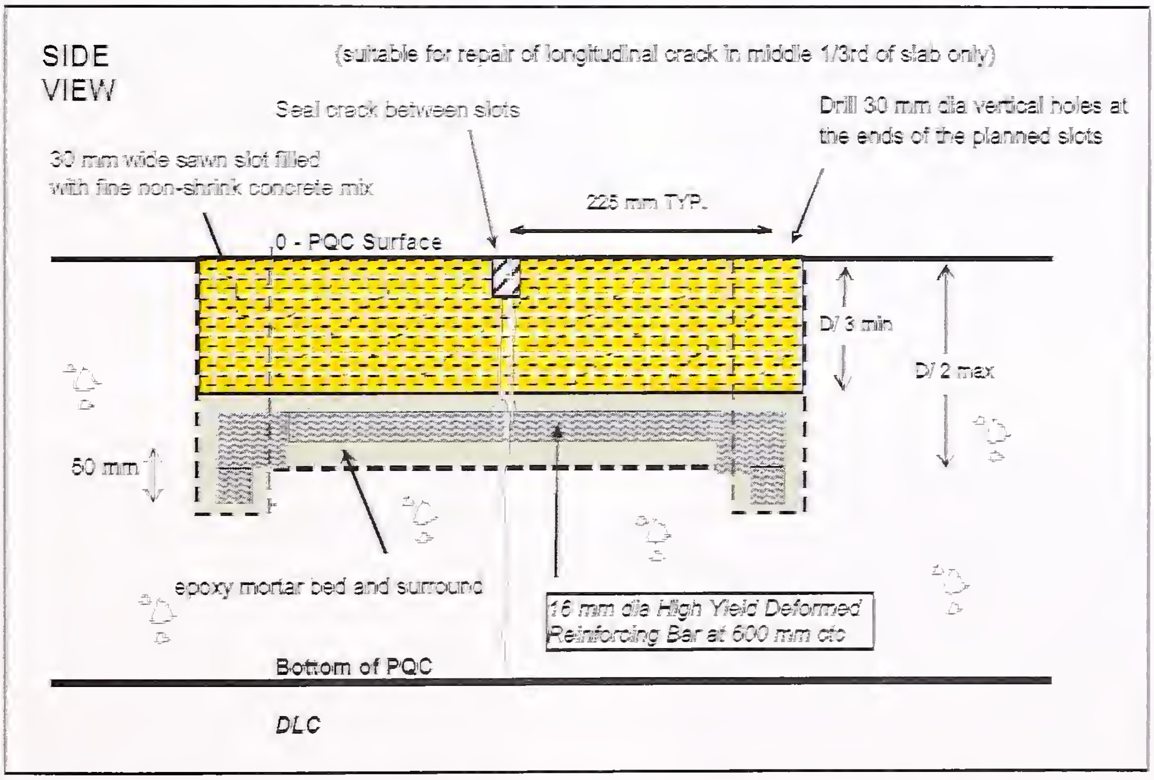


Fig 7.3. Typical Arrangement Stapling with 16 mm dia Tie bar

8. PARTIAL DEPTH REPAIR

8.1. General

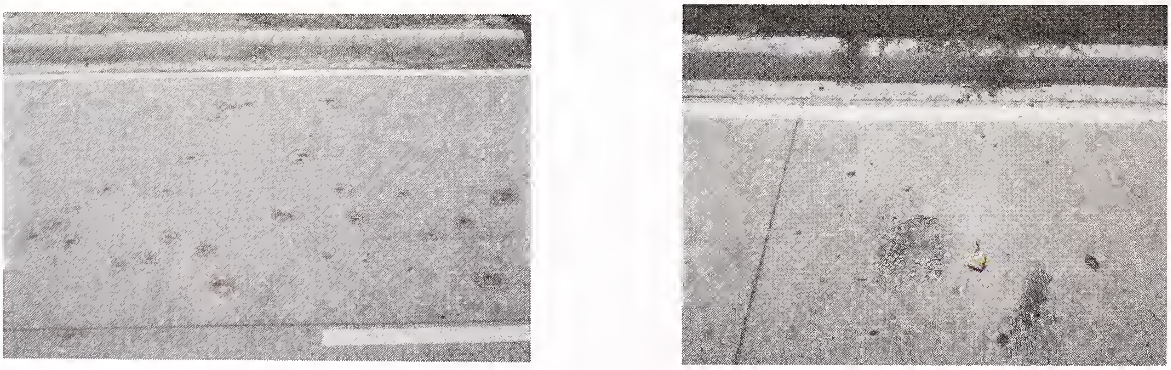
Partial depth patches are acceptable for most surface distress types at joints, cracks, and mid slab locations that are within the upper third of the slab. The most common distress type requiring partial-depth repair is spalling as shown in **Fig. 8.1**, but partial depth repair can also be used for restoring small areas like popouts and potholes as shown in **Fig. 8.2.** Table 4.5 shall be referred to for selecting suitable cases for this type of repair.

For severe, shallow and surface defects, spalling is typically a random and localised distress. Surface spalls create a rough ride and can accelerate development of further distress. Partial depth patches replace unsound concrete to restore surface evenness and arrest further deterioration. They also provide proper edges for resealing joints and sealing cracks.

Joint edge spalls mostly result from poor workmanship (compaction and or finishing) whilst starting the next days work at a construction joint, penetration of incompressible materials in the joint groove and slab curling and warping. Partial depth patching can only repair spalls in the upper third of the slab, when load transfer devices are in good condition.

a) Shallow Spalling at the Joint b) Spalling 2nd Day Concrete

Fig. 8.1. Typical Spalling at Joints



a) Popout b) Potholes

Fig. 8.2. Popouts and Potholes

Partial-depth patches are usually very small. Each patch usually covers an area less than 1 m^2. They are often only 60 mm to 75 mm deep depending on the patch material used. The area to be repaired shall extend 50 mm beyond the spall limits and be at least 100 mm x 250 mm (in plan) x depth. The depth is normally 65 mm deep minimum (+15 mm) for epoxy mortar/polymer concrete type repair or 40 mm deep (+/- 10 mm) for elastomeric concrete (See **Fig. 8.3).** Shallower patches have a tendency to break up and breakout under traffic (See **Fig. 8.6).** Small steel studs cut from reinforcing bar may be drilled and epoxied into place in an approximate grid pattern (100 mm x 100 mm) to provide an extra key effect similar as shown for the treatment of popouts as shown in **Fig. 8.5.**

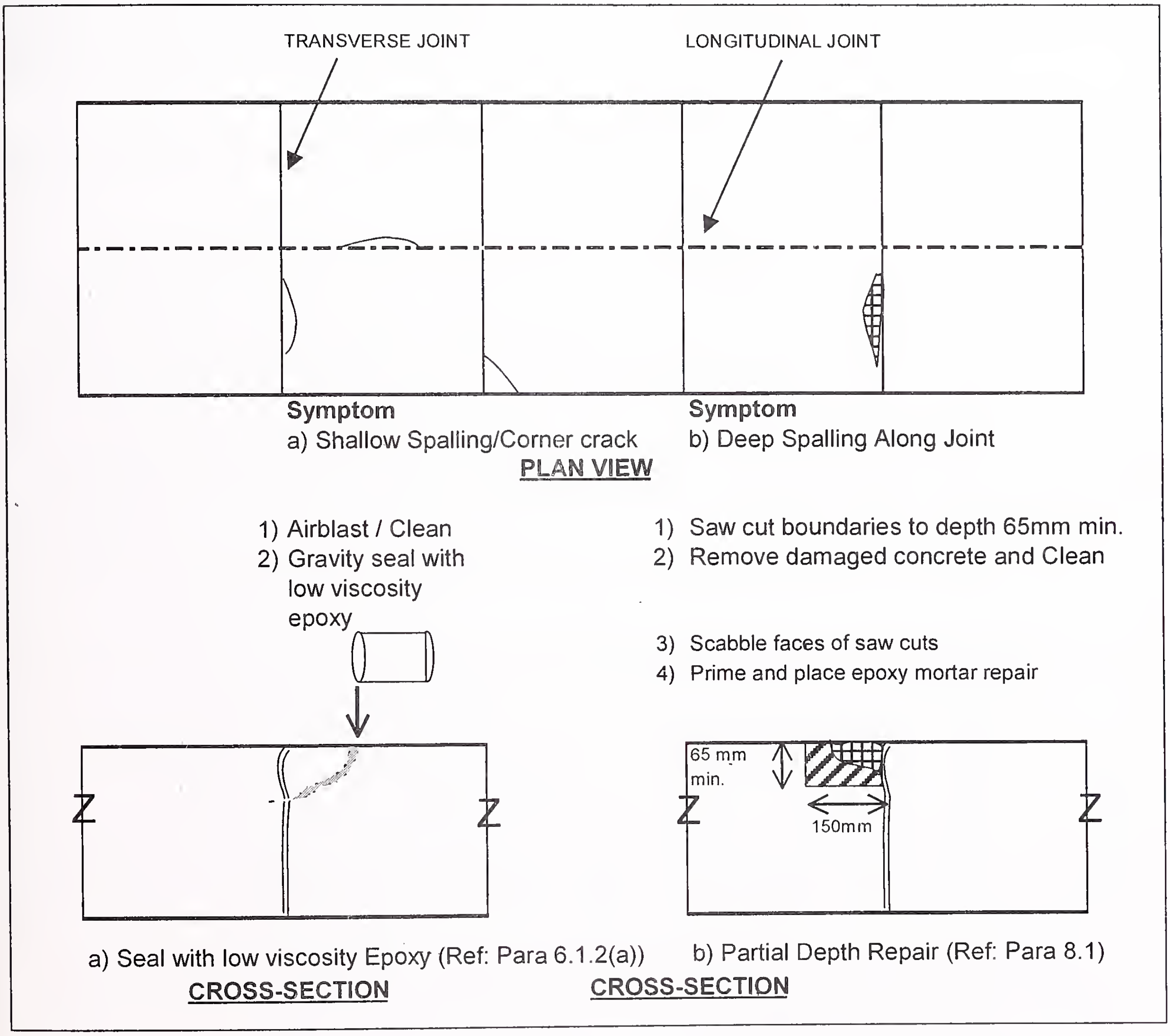


Fig. 8.3. Repair of Shallow Cracking and Spalling Near the Joints

8.2. Methodology for Partial Depth Repairs

Partial depth repair comprises of the following tasks:

(i) The area to be treated is marked following the guidelines set out in Para 5.6.

(ii) The materials and procedure are selected for patching in consultation with the Engineer-in-Charge.

(iii) The upper 50 mm of the concrete (or deeper if the spall is wide but not deeper than one third of the slab thickness) is saw cut parallel to the joint. The patch shall not expose any dowel bar or reinforcement. If a dowel bar or reinforcement is exposed the surrounding concrete shall be completely removed to at least 25 mm below the bar or wire as shown in **Fig. 8.3** for typical layouts.

(iv) The upper/unsound concrete layer between the joint and saw cut is chipped out; by manual or mechanical chipping.

(v) Loose material is removed from the pit of the patch and clean the repair area.

(vi) The pit surface is cleaned eliminating all dust and exposing the concrete grain texture: (a) check the air blown by the compressor for oil and moisture with the help of a cloth; (b) sandblast the surface to remove dirt, oil, residual unsound concrete and laitance and to improve texture; (c) airblast the surface to complete cleaning; (d) check the prepared surface for cleanliness by rubbing across with the hand or a cloth; if the pit is not immediately patched, cleaning operations shall be repeated.

(vii) The patch pit is checked for unsound concrete before starting the patch. If unsound concrete is detected it should be removed and the pit cleaned again by airblasting.

(viii) During spall repair, the existing joint groove shall be protected against leaking of fresh resin or cement mortar that could build bridges between the two slabs. If non-flexible patch material is used an oiled piece of plyboard should be placed to form a bond breaker plate in the adjacent joint(s) to avoid penetration of patching material in the joint. The bond breaker plate should be inserted 25 mm deeper than the patch and should have the same upper level as the slab. Laterally the plate should extend 75 mm on both sides of the patching hole. The bond breaker plate should be slightly thicker than the joint opening and be slightly compressed after installation. Latex caulking can be used to seal any gaps between the bond breaker plate and the joint opening.

(ix) The bonding agent is mixed carefully according to the manufacturer's instructions. A small (Jiffy) mixer with 20 litres capacity may be used to mix the two components during the specified time.

(x) The clean surface of the patch hole is coated with the bonding agent (water cement slurry, resin, etc. as specified by the manufacturer) for a certain time before the patching mix is brought. The bonding agent should not be allowed to collect in pockets and it should be at the appropriate consistency (sticky) when the patching operation starts.

(xi) The patching mix is prepared using a small drum or paddle-type mixers with capacity of about 0.2 m^3. A small Jiffy mixer may be used for smaller patches. Aggregates and binder may be previously weighed and bagged. Mixing times and proportions are strictly observe. Too long mixing will reduce the short time that is available to patch.

(xii) The patch materials are placed by slightly overfilling the pit to allow for volume reduction during compaction/ screeding. Aggregate mixes shall be placed with a shovel, because dumping from buckets or wheelbarrows causes segregation. Cementitious mixes shall be vibrated to release entrapped air. The vibrator shall be held at 15^0 - 30^o from the vertical and lifted up and down until the whole patch is covered. It should not be moved horizontally in the patch. Some patches may be too small for the use of internal vibrating needles and vibrating screeds. Rodding and tamping or cutting with a trowel or other small hand tool is acceptable.

(xiii) Some polymer mixes including epoxy mixes which have high heat of hydration, should in certain adverse conditions, be placed in several 38 mm to 50 mm thick lifts with waiting times between lifts as recommended by manufacturers.

(xiv) Proprietary patch materials shall be cured as recommended by the manufacturers. Some require some type of moist curing whereas others need application of specific curing compounds and a few others may be air-cured.

8.3. Partial Depth Repair Using Epoxy Mortar Formulation

Partial depth repair using epoxy mortar formulation should be carried out according to the following steps:

(i) **Surface Preparation:**

Firstly the affected portions are firstly made free of all loose and unsound materials. The surface is kept clean and dry at proper temperature. Care is taken that moisture does not rise through capillary action at the interface of resin and concrete during application and curing period. There are following three cases of surface preparation depending upon the distress type.

Case I - When Concrete is to be Cut to a Depth: For removal of unsound concrete and loose concrete, chisel and hammer manually or pneumatically can be adopted. If possible, the sides may be given a slight slant to that of the base of the groove, so formed is somewhat wider than the top to ensure better keying for the repair work. If a joint cutting machine is available, 10 mm - 20 mm deep peripheral cuts at the top can be made initially.

Case II - When Cutting in Depth is not Required: Those surfaces or areas which are sound and do not require concrete removal in depth, are thoroughly cleaned to

remove oil, dirt, asphalt, mortar droppings, weak laitance etc. Light chiseling (upto a depth of 1 mm) is beneficial even where extraneous matter are not present at the surface. If neither chiseling nor sand blasting can be adopted, the cleaned surface may be treated with dilute hydro-chloric acid @ 4 kg/10 sq. m. in two applications. Sand blasting and chiseling are, however, to be preferred over acid treatment.

Case III - When Shallow Fine Cracks are to be Repaired: For repair of shallow fine cracks or cracks with no edge spalling, no surface preparation beyond cleaning the strip of concrete on either side of the crack is needed. In case of wider, spalled cracks, all foreign matter including joint sealing compound used to seal them are fully removed from in and around the cracks with the help of rakers and chisels. Any unsound concrete around the crack is also chiseled out or grouted or cut out with the small diameter concrete saw. The prepared notch should be at least 3 mm to 4 mm deep.

(ii) **Cleaning Before the Repair:** The prepared surface, recess or groove may be blasted with compressed air to clean it thoroughly and made dry before the repair application.

(iii) **Application of Tack Coat/Cement Slurry:** All resin repairs commence with the application of a tack coat on the prepared concrete surface formulation which is selected for use in the resin mortar/resin concrete for the repairs. Normally one coat of tack coat for horizontal surface, and two coat application for vertical faces may be applied. The approximate amount required is 3.2 kg/10 sq.m. for epoxy resin formulation.

8.4. Methodology for Repairing Popouts

This procedure as illustrated in **Fig. 8.4** excludes saw cutting the boundaries of the patch and is typically required for treatment of popouts/potholes and spalling.

The procedure is as follows:

(i) Chipping starts in the middle of the patch and progresses to the borders. The chisel point shall be directed towards the inside of the patch at about 45°. Hand tools or a light electric chiselling machine of weight 6.8 kg maximum with spade bit may be used.

(ii) Drill and epoxy grout in stud.

(iii) Prime with low viscosity epoxy on bottom and vertical sides.

(iv) Fill the patch with epoxy mortar (1:3).

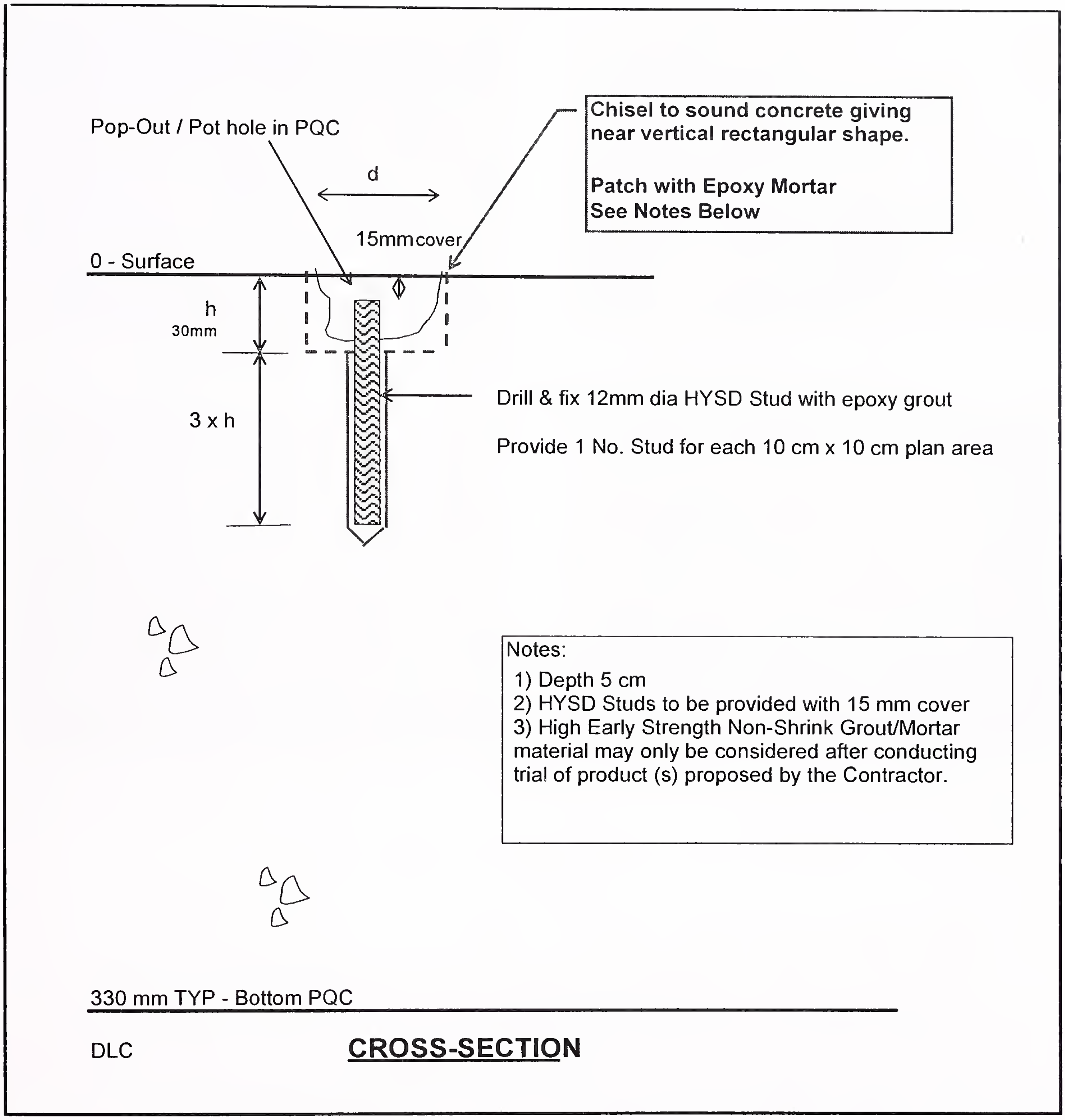
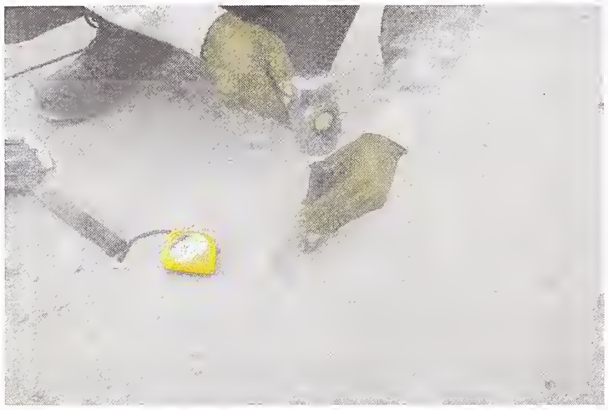


Fig. 8.4. Methodology for Repairing Popouts

This procedure has the following advantages:

(a) The rough vertical edge promotes bonding.
(b) There are no saw overcuts.
(c) Fewer steps and smaller crew than for the saw and chip procedure.
(d) Spalling is controlled by using the 6.8 kg jackhammer.
(e) May be faster than the saw and chip procedure if mechanical tools are used.
(f) A saw is only needed for joint sawing.

1) Marking out the Popout for Chiselling



2) Chiselling to Sound Concrete in Rectangular Pattern

3) Popout Ready for Epoxy Repair

4) Repaired Popout

Fig. 8.5. Photographs Illustrating Repair of Popouts

This procedure has the following disadvantages:

(a) Sound concrete may be damaged by heavy hammers.
(b) Jackhammers can cause feathered edges.

8.5. Potential Problems with Large Partial Depth Repairs (PDR)

Partial depth repairs are generally susceptible to failure over a period of time. The causes of failure of partial depth patches can be design, material or construction related failure of a large epoxy patch and cementitous patch.

(1) Design-related causes of large partial depth patch failures are the following:

(a) Exclusion of some deteriorated concrete from the repaired area.
(b) Incompatible climate conditions materials or procedures.
(c) Thermal incompatibility between repair mixes and the slab concrete.

(d) Climatic conditions during the service life that are beyond capability of repair materials.
(e) Inadequate cure time after the repair.
(f) Inadequate opening time after the repair.
(g) Incompatibility between joint bond breaker and sealant material.

(2) Construction-related causes of shallow partial-depth patch failures are the following:

(a) Failure to square the hole.
(b) Deteriorated materials not completely removed.
(c) Inadequate cleaning, namely laitance (sawing slurry) adhering to surface.
(d) Lack of bond (poor surface coating or inappropriate surface condition).
(e) Failure to re-establish the joint (compression failure).
(f) Variability of repair material.
(g) Insufficient compaction of fresh patch mixture.

Full depth repair is the recommended choice during the construction stage for minimising risk of dealing with this type of failure after 2-3 years traffic or less.

Epoxy mortar is susceptible to brittleness over a period of time when exposed in large areas to UV or direct sunlight. Epoxy mortar may be modified by adding at-least 5% poly-sulphide polymer in the epoxy resin. Such formulation will improve the life of the mortar by giving some flexibility and improving UV resistance. Epoxy mortar supplied packed in correct proportions are recommended. But still care has to be taken not to mix too much material at a time otherwise there will be un-necessarily waste.

8.6. Problem Associated with Longitudinal Tining

Tining is the preferred method for texturing fresh concrete. It is generally provided transversely. Longitudinal tining is new to India and has been adopted in few projects under NHDP on trial basis. Certain adverse observations have come to notice after passing of traffic over a relatively short period of time (less than 4 months). The edges get abraded in the wheel path and shallow spalling develops at irregular interval along the pavement. This affects the surface evenness and riding quality. **(Refer Fig. 8.7).** In Indian condition, with heavy rainfall and high proportion of slow moving vehicles transverse tining may be preferred, even though these are little more noisy and little less aesthetic.

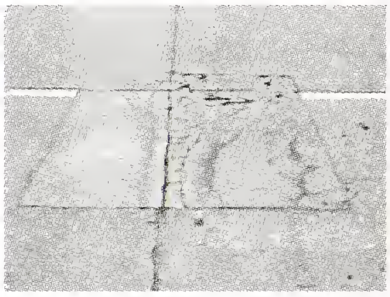
1) Epoxy Repair of Large Potholes in a severely cracked Slab. Further deterioration and additional Cracks developed

2) Epoxy Repair of Spalled Joint **without saw cutting.** Failure at feathered edges

(a) Photograph Illustrating Failures of Partial Depth Epoxy Repairs

1 a) Preparation for Cementitious Partial Depth Repair (Oct'05)

1 b) The Completed Patch after 6 months (Mar'06)



1 c) The Condition after 20 months (Aug'07)

(b) Failures of Partial Depth Cementitious Repairs

Fig. 8.6. Typical Failures of Partial Depth Repairs (Para: 8.5)

Fig. 8.7. Abrasion in the Wheel Paths (Longitudinal Tining)

9. FULL DEPTH REPAIR

9.1. General

This is the ultimate repair treatment. Table 4.5 shall be referred to for selecting suitable cases for this type of repair. If this treatment does not succeed an overlay is to be used either alone or along with full depth repair. The procedures to be followed for whole slab replacement are broadly similar to full depth repair as described in this Chapter. Full depth repair may be considered as the preferred repair option in the following situations.

(i) Partial depth repair has failed
(ii) The cross-stitched longitudinal joint has again failed
(iii) The crack which was less than D/2 has propagated more than D/2 or full depth and the slabs across the crack are rocking
(iv) The slab has shattered and can no longer support the load of traffic
(v) The spalling along the joint or crack is more than 50% depth of slab thickness
(vi) The corner break is down to full depth
(vii) Failure of pavement due to dowel bar locking and serious cracks along the joint have developed
(viii) Blow-up at expansion joint.

Full-depth repair entails removing and replacing at least a portion of a slab down upto the bottom of the concrete. Full-depth repair improves pavement surface evenness and structural integrity and extends the pavement service life. The most common problem that requires full-depth repair is full-width cracking near the joints and joint deterioration. This includes blow-up and any cracking, breaking, or spalling of slab edges on either side of a transverse or longitudinal joint. Often, spalling takes place on the bottom of the concrete slab and may not be visible from the surface. Spalls that extend 75 mm to 150 mm from the joint are an indication that additional spalling could exist below and would require full-depth patching (Refer **Fig. 9.1).**

Full-depth repair is also necessary to repair any deep corner breaks or any slabs with more than one intersecting full depth crack. The latter may result from lack of uniform support or inadequate structural strength. The minimum dimension of full depth repair in longitudinal or transverse direction should be 1.5 m. Some of the details of **Figs. 5.5** to **5.8** may also be referred in this context. For multiple corner breaks or slabs with intersecting cracks, their size may correspond to the area of an entire slab. Before full-depth patching the sub-base and separation layer shall be reinstated as required, **(Fig. 9.2).**

9.3.2. Replacement of a portion of a slab comprises the following tasks:

(i) The area to be treated is marked according to the guidelines in para 5.6 and 5.7 in Chapter 5.

(ii) The materials and procedure are selected for patching in consultation with the Engineer-in-Charge The patch mixes for full-depth repairs often use ordinary or rapid hardening Portland cement as per the need and also proprietary cement that gain strength early (Appendix B). A job mix design shall be tested in the laboratory with a target slump of 20 - 40 mm. To decrease the water-cement ratio a water-reducing admixture may be required for Grade 43 or Grade 53 cement (IRC:44-2008 may be referred for mix design).

(iii) The portion to be replaced is cut out and removed. The perimeter of the area to be repaired shall be cut with a concrete saw to the specified depth. Transverse perimeter cuts are first made around the boundary of the repair down to about a quarter (1/4) to a third (1/3) of the slab thickness. Separate full depth cuts are then made for removal of the slab (See **Fig. 9.1**). The concrete between the two cuts provides a buffer to prevent undercut spalling and allows chipping for exposing the steel dowel/ tie bar reinforcement. Always cut toward the shoulder so that any shear force developed from the compression of the slabs get concentrated and relieved in the paved shoulder portion.

(iv) The advantages of sawing patch boundaries include the following:

(a) The saw leaves vertical edge faces
(b) During breaking, the patch area is isolated within the sawed boundaries and the risk of damage of the adjacent slab areas is therefore minimised
(c) Spalling of adjacent slab areas is also minimised
(d) Breaking, chipping and removing debris within the sawed boundary is usually easier and faster
(e) After sawing the lane may be reopened to traffic for two days before proceeding with the repair work

(v) The disadvantages of sawing patch boundaries include the following:

(a) More workers are required than for other procedures
(b) Water used to cool the saw-wheel saturates the repair area and drying time may delay the work
(c) Saw overcuts beyond the corners of the patch result in weak areas that shall require to be cleaned and sealed
(d) Saw polished vertical patch boundaries provides poor bonding. This is alleviated by manual chiselling or by means of light jackhammers

(vi) Holes are drilled for dowel bars or tie bars in the edge walls of the remaining slab portion. Rather than single hand-held drills, it is better to provide enough space for using dowel-drilling rigs with wheels to properly control alignment and wandering. Both standard pneumatic or hydraulic percussion drills are acceptable. They drill a

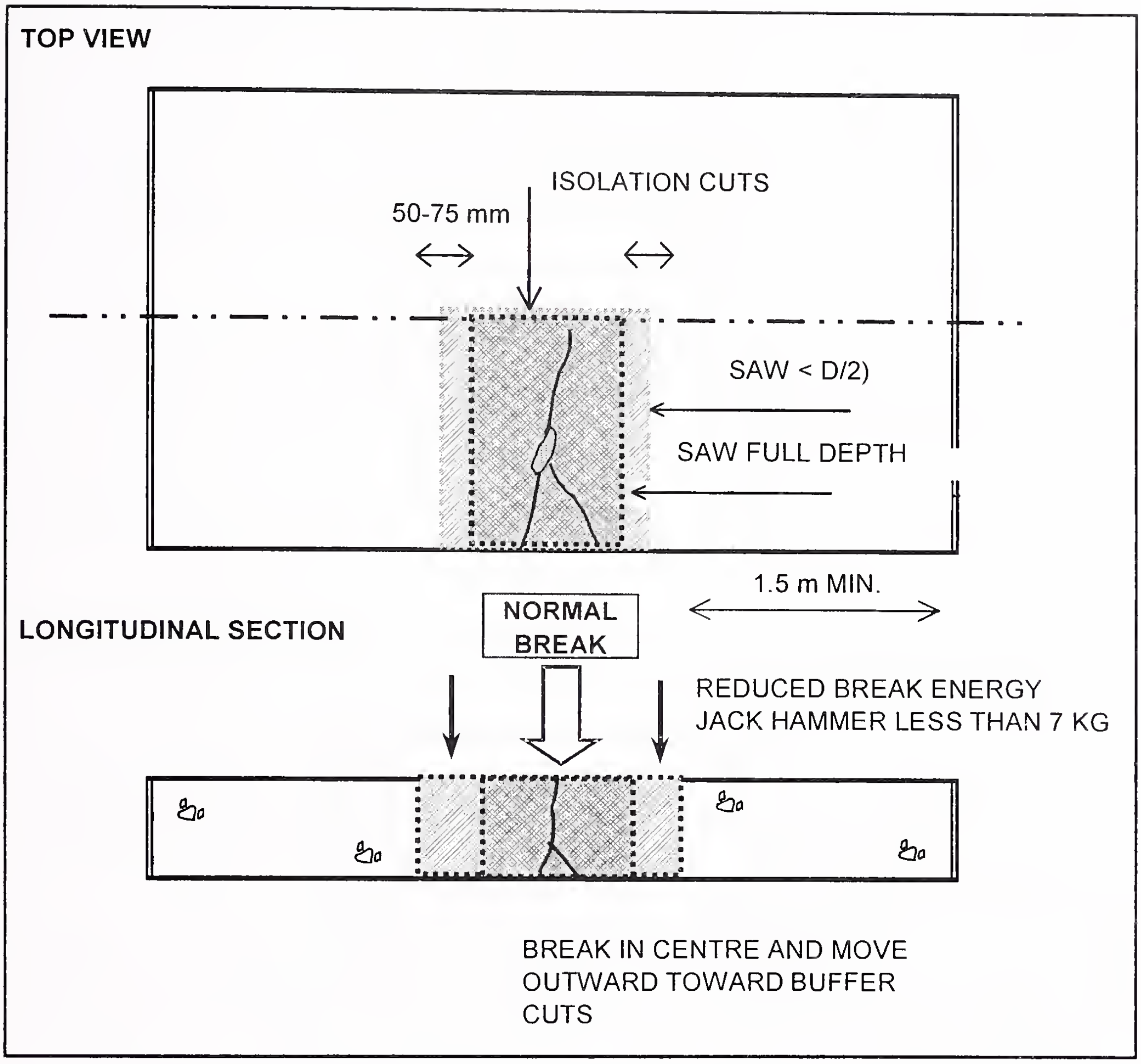


Fig. 9.1. Buffer Cuts for Protecting Repair Perimeters from Undercut Spalling
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hole in about 30 seconds. Electric pneumatic rotary drills take three to four times longer. The hole shall be 2 mm bigger than bar diameter for epoxy anchor material or 6 mm bigger than the bar diameter for cement based anchor material.

(vii) The dowel hole is cleaned carefully by means of a nozzle and compressed air. Prior to this operation ensure that the compressor is not blowing oil and moisture contaminated air by blowing into a piece of dry cloth.

(viii) The epoxy anchoring material is fed to the back of the hole before inserting the dowel/ tie bars. This ensures that the anchoring material will flow forward along the entire dowel/tie embedment length during insertion and decreases the likelihood of leaving voids between the dowel and concrete.

(ix) Reinforcement is fixed in top of the repair when the length to width ratio of the patch exceeds 1.5 so as to control any cracking on account of the shape factor. (10 mm dia

high yield deformed bar @ 200 mm c/c in both directions). The reinforcement shall be placed about 75 mm below the top surface.

(x) Concrete is poured in the pit from ready mix or batch trucks, or site mixed for small jobs in small mixers. Evenly distribute and compact the mix by penetration of a vertical vibrator. Special care is important to compact concrete in the corners, along the patch perimeter and around the dowel bars.

(xi) Strike off and finish the concrete surface with a vibrating screed or manual screed depending upon the size of work. Hand finishing should be minimum as it will leave undulations in the surface.

(xii) A wire brush/tyned texture is applied to get surface texture to match the existing pavement.

(xiii) Suitable curing conditions are provided immediately by means of a liquid membrane curing compound.

(xiv) Laboratory tests shall be performed in advance to determine the appropriate mix proportions and establish the time required to achieve the minimum compressive strength required to open to traffic. The minimum compressive strength of repairs before opening to traffic should not be less than 32 MPa.

(xv) The methods for placement and curing the concrete shall take into consideration the weather, seasonal and other environmental factors.

(xvi) **Fig. 9.2** gives further details about the Full Depth Repair (FDR).

9.3.3. Replacement of a whole slab comprises of essentially the same process except that after removal of damaged slabs it is important to check the causes of damage that could be poor drainage or lack of support. Before reconstruction the sub-drainage system and the sub-base shall be repaired as appropriate and the interface reinstated. This repair procedure for replacement of a whole slab is otherwise the same as that of full depth repair described in this Chapter. New dowel and tie bars shall also be retrofitted, if required **(Fig. 11.1)**.

9.3.4. Whole slab replacement requires fixing tie bars along the longitudinal joint. Drill holes to suit 16 dia deformed reinforcing bars with embedment length appropriate to the anchor material. Hand held drills are acceptable because alignment is not critical.

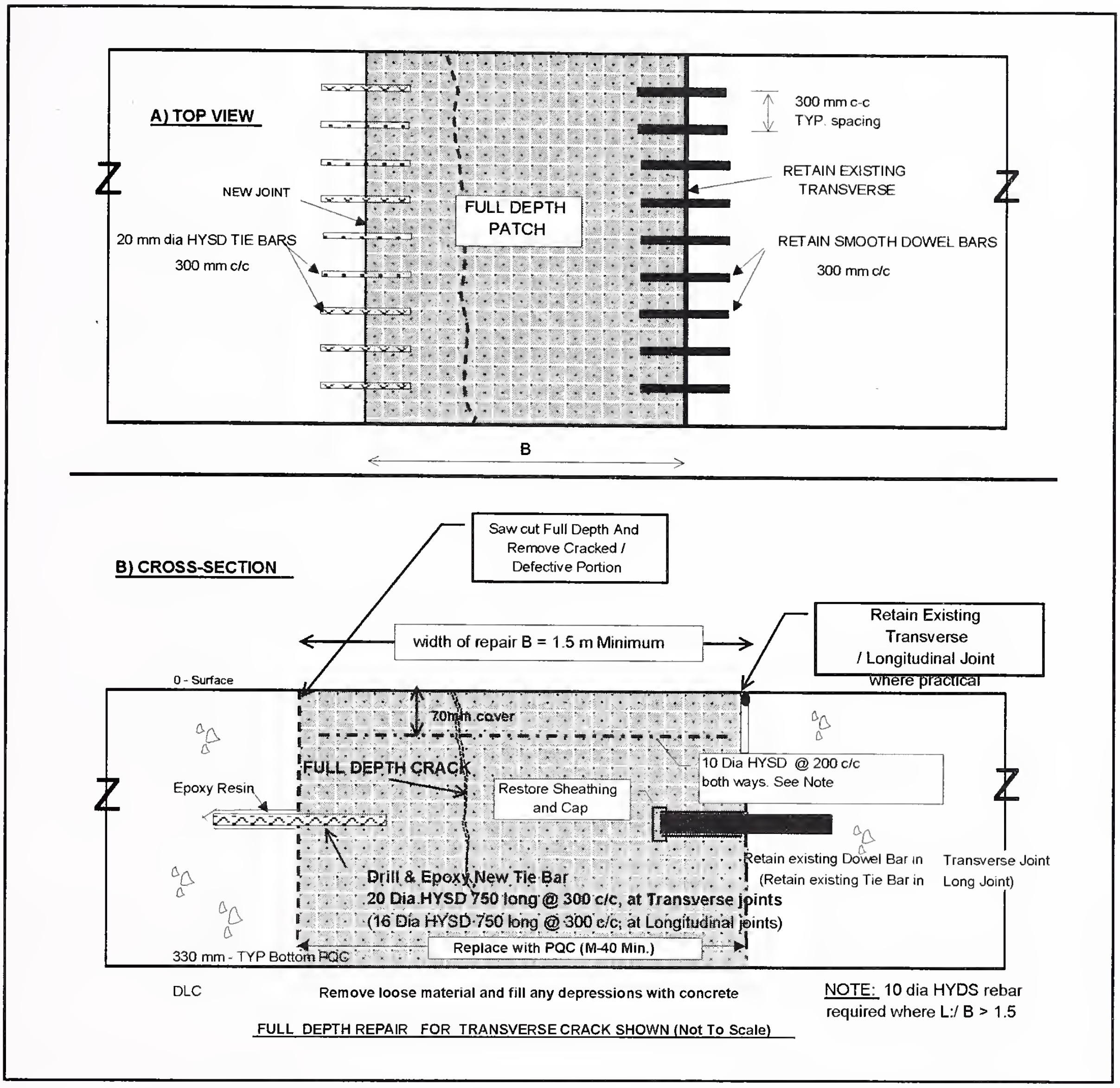


Fig. 9.2. Full Depth Repair of Cement Concrete Pavement

a) Secondary cracking due to release of stresses in adjoining slabs initiated by the saw cutting.

b) Saw blade jammed in the saw cut. This problem can be prevented by placing metallic wedges progressively along the saw cut to transfer stresses to the adjoining slabs.

Fig 9.3. Problems to be Avoided During Full Depth Saw Cutting

10. SLAB STABILISATION

10.1. General

10.2.1. Slab stabilisation refers to the method for raising sunken slabs by pressure grouting under the slab after boring vertical holes for pressure injection of the slurry. It is also sometimes called undersealing or sub-sealing. It is most often performed at areas where pumping or loss of support has occurred . The most common materials are cement and fly-ash grouts or polyurethane mixture etc. selected according to the fluidity, durability and cost.

10.2.2. Several common destructive forces cause voids under concrete pavements. Heavy traffic loads induce the highest slab deflections near transverse joints and working cracks away from transverse. Deflections may cause erosion, consolidation, with the resultant loss of the sub-base or sub-grade support. Without support underneath the slab, load stresses in the concrete increase and may cause other problems, such as faulting, corner breaks, and cracking. The voids usually occur near cracks, joints, or along the pavement edge, and are often not more than 3 mm to 4 mm deep. The grout fills these voids beneath the concrete pavement slab or sub-base layer and displaces free water. Transverse joint faulting and presence of water at or near joints and cracks on the traffic lane or shoulder are good indications of pumping and voids. Corner breaks and shoulder drop off are further indicators of voids under the slabs.

10.2.3. Slab stabilisation is intended to fill the voids beneath the slab. Slab Stabilisation requires an effective method for locating the voids. This may be done by the following evaluation methods, but each has its limitations.

(i) Visual inspection: This method has several deficiences especially when evaluating effectiveness of stabiliastion.

(ii) Deflection measurement by FWD (Falling Weight Deflectometer).

(iii) Ground Penetrating Radar (GPR).

10.2.4. The principle requirements in selection of materials are strength and ability to flow into or expand to fill the very small voids and water channels. The main advantage of polyurethane grouts are the tensile strength and fast cure time. But usually pozzolana-cement grouts are preferred due to availability and cost effectiveness.

10.2.5. A typical pozzolana cement grout uses one part cement to three parts pozzolana. Quantity of water is typically in the range of 1.5 to 3 parts by weight of mix. Tests shall be conducted thoroughly, i.e. 1, 3 and 7 day compressive strength, flow cone times and initial set times. Engineers use the flow cone during the concrete mix design process to determine the quantity of water required. The Contractor shall check the grout consitency twice each day using the flow cone (ASTM C 939).

10.3. Pressure Grouting

It comprises the following tasks:

(i) The repair materials and procedure are selected.

(ii) Holes are drilled for grout injection using pneumatic or hydraulic rotary percussion drill on a 1 m square grid over the whole area of voids to be filled under the slab; drill depth = slab thickness + 20 mm, drill vertical hole Ø = 30 mm - 50 mm as appropriate to best use the available equipment, distance to joints and cracks = 0.5 m to 1.0 m.

(iii) Compressed air is blown to remove water etc under the slab for the grout injection. The work sequence should be across and along the slab going downwards crossfalls and longitudinal gradients.

(iv) Grout is injected in each hole at a pressure of 0.35 N/mm^2 working in sequence across and along the slabs, until the void accept no more grout or grout flows up through an adjacent hole or the slab begins to rise. A short pressure surge up to 2.0 MPa may be necessary to clear debris from the grout hole for 2-3 seconds only.

(v) For early and fast flow of grout and to minimuse air beneath the PQC two holes are drilled, vacuum pump may be used by sucking air from second hole.

(vi) Excess grout upon completion is removed from the pavement surface. If resin grout was used that cannot be removed the slab surface may be blinded with fine hard aggregate.

(vii) Injection holes are cleaned and filled with cement or resin mortar.

(viii) Traffic is opened only after the minimum appropriate curing time.

10.4. Vacuum Grouting

Vacuum grouting comprises of the following tasks:

(i) Holes are drilled for grout injection on a 1 m square grid over the whole area of voids to be filled under the slab.

(ii) The holes are temporarily plugged and the slab surface is swept to clean all debris.

(iii) Vacuum channels are placed in position.

(iv) Transparent flexible plastic sheet is placed over the area to be grouted on top of the vacuum channels.

(v) The perimeter of the plastic sheet is sealed. The vacuum injection holes are sealed to prevent ingress of air.

(vi) Vacuum is applied and any water from the void beneath the slab is drawn off **(Fig. 10.1)**.

(vii) With the vacuum applied puncture the plastic sheet at the injection holes and pour grout in each hole in the working sequence. The hole is plugged as soon as grout begins to be drawn up.

(viii) Upon completion excess grout shall be removed from the pavement surface.

(ix) Vacuum injection holes are cleaned and filled with cement or resin mortar.

(ix) The traffic is opened after the minimum appropriate curing time.

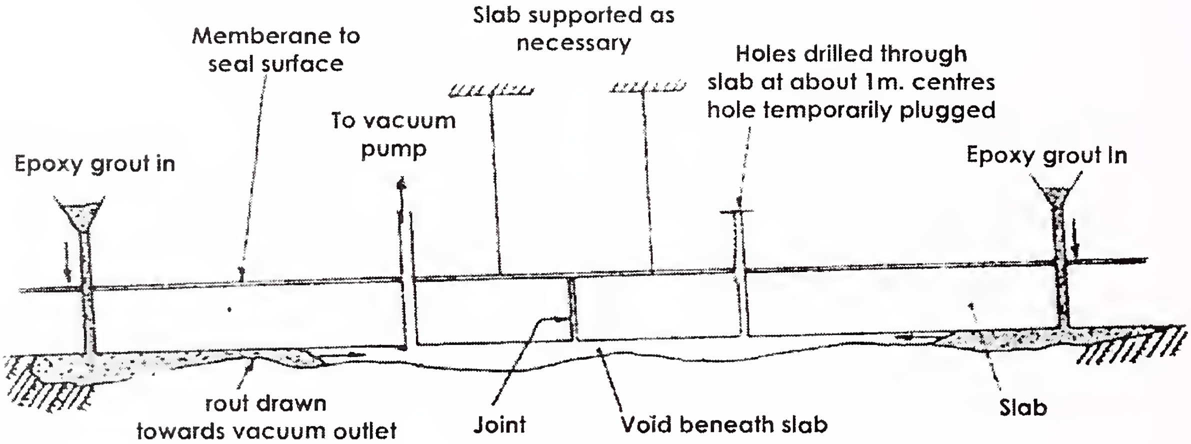
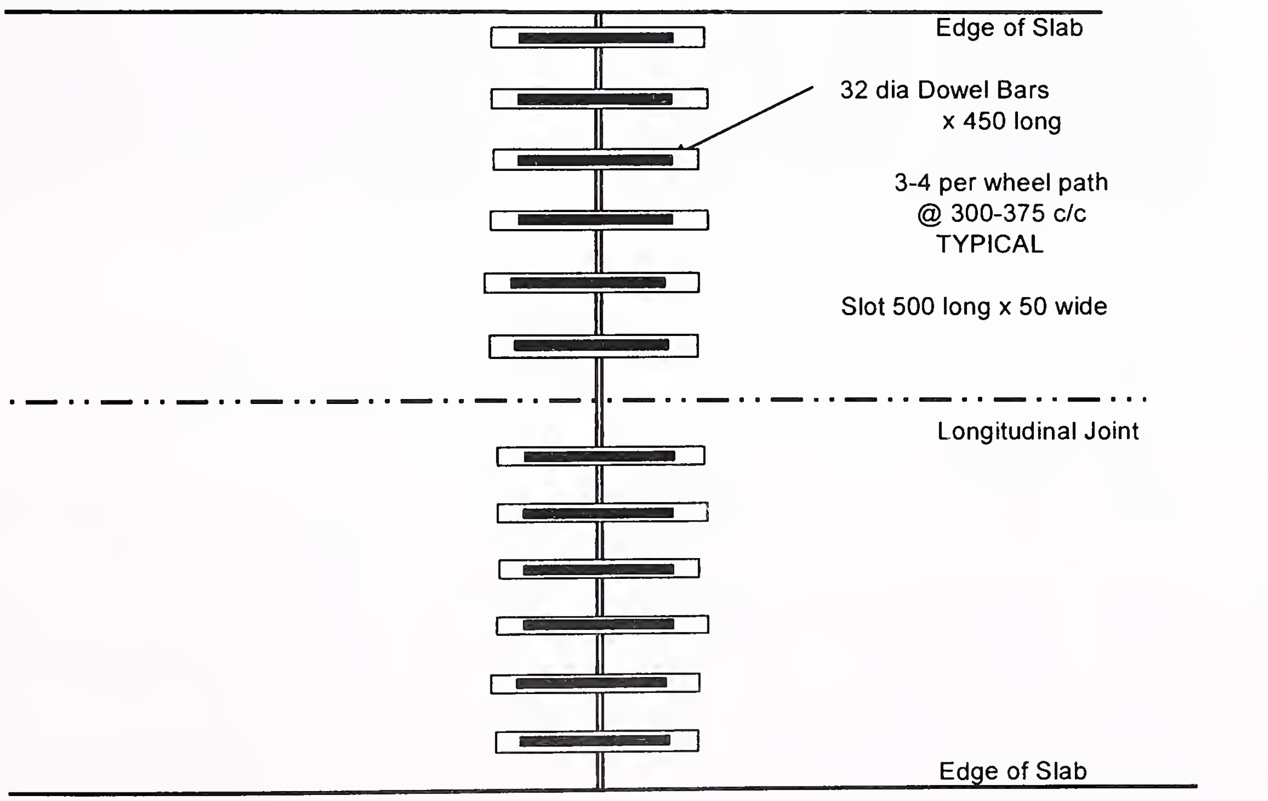


Fig. 10.1. Vacuum Grouting with Epoxy or other Repair Material

11. SPECIAL TECHNIQUES FOR REHABILITATION OF RIGID PAVEMENTS

11.1. Repair for Load Transfer Failure (Retrofit of Dowel Bars)

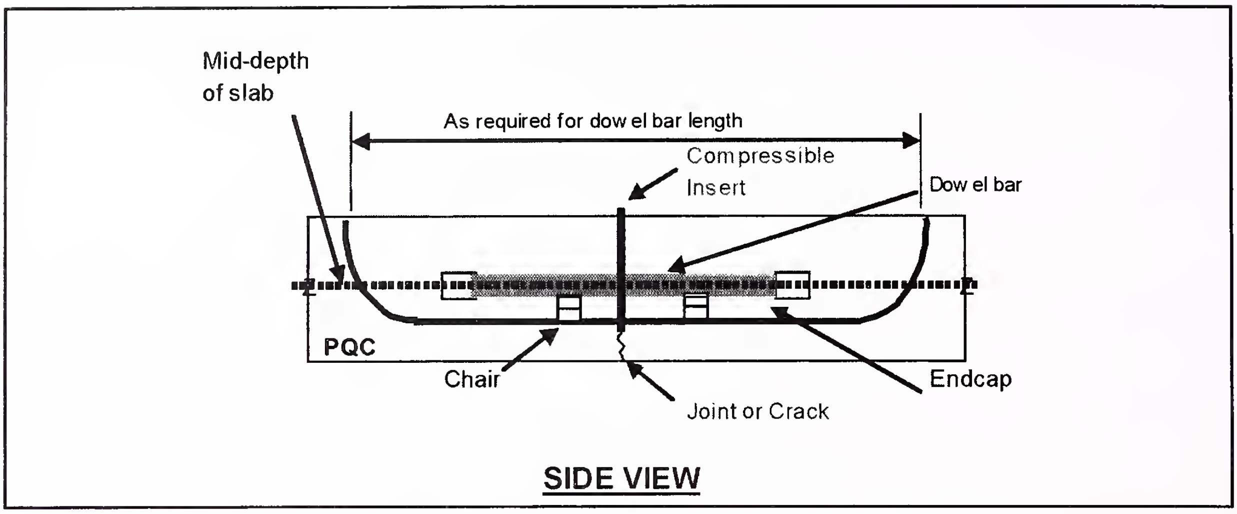
11.1.1. New dowel shall be placed at cracks where displacements occur and at joints if the existing bars are damaged (misaligned, bent or corroded dowels, dowel socketing or dowel slot widening, pavement lock-up). At least three bars in every wheel track at 300-375 mm spacing **(Fig. 11.1(a)** shall be installed as per procedure given below. For existing dowel bars, there can be two ways of retrofitting. If there are no cracks along the existing dowel bars, the retrofit slots can be cut out in the land space between the existing bars and new bars be installed. However, if the existing bars are corroded or surrounding concrete is cracked, the retrofit slot be cut out encompassing the damaged bar. This tantamounts to replacement of dowels by retrofit. The spacing is 300-375 mm. This repair method re-establishes load transfer across the joint or crack, while at the same time allowing longitudinal movement. Poor load transfer may originate faulting, subbase damage, corner breaks, or spalling. **Fig. 11.1** shows this type of repair for load transfer failure.



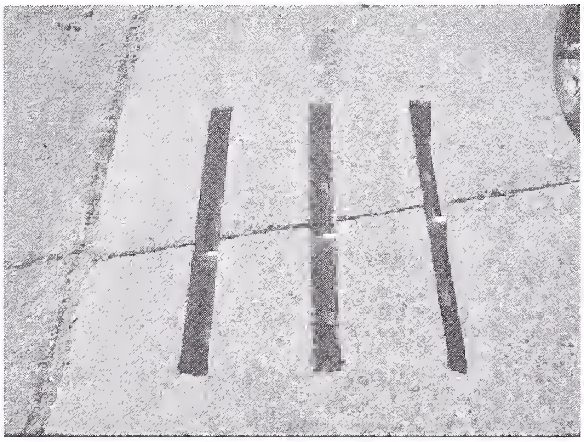
Layout of Dowel Bars

a) Plan

Fig. 11.1. Retrofit Dowel Bars



b) Side View



c) Pavement after Cutting Slots for Dowel Bar Retrofit

d) PQC after Repair

Fig. 11.1. Retrofit Dowel Bars

11.1.2. The work procedure for retro-fitting dowel bars consists of following steps:

(i) The repair materials are selected

(ii) The slot to be cut is marked parallel to the centre line of the pavement with a length of about 800 – 900 mm ensuring half length on either side of crack/joint.

(iii) Vertical holes (40 mm diameter) are drilled at the ends of the planned slot to such a depth that the dowel bar centre line will be in the middle of the slab thickness.

(iv) The slot sides are cut and the bottom sides are levelled between the holes drilled at each end. Diamond-saw slot cutting is the most reliable and proven method. Diamond-saw slot cutting machines can make multiple cuts to form the edges of three (one wheel path) or six (two wheel paths) slots. The saw operator aligns the head before the joint or crack then plunges into the concrete and advances across the joint or crack. The plunging and moving back and forth across the joint or crack creates a flat bottom at the required depth.

The jack hammer may be placed either at the end of the fin or downed along the bottom or along the side of the slot to break the fin. The fin may be removed easily in two or three big pieces. The fins can also be removed manually with the help of hammer and chisel. The small projections at the bottom of slot be broadly flattened with small jack hammer or manually with hand hammer and chisel. The slots are cut parallel to the centre line of the pavement. The slots are 50 mm to 65 mm wide and slightly deeper than half the slab depth so as to ensure that dowel is at mid depth of slab. The outside wheel path dowel is between 300 mm to 375 mm from the pavement edge and the inside wheel path dowels shall be 450 mm to 600 mm inside the centre line of the pavement. The spacing between the dowels may be between 300 mm to 375 mm centre to centre.

(v) Joints and transverse cracks with a load transfer of less than 40% shall be retrofitted with dowels prior to diamond grinding. The total deflection of slabs shall also be checked to ensure that it is less than 0.8 mm. If the deflection is greater than 0.8 mm the slabs should be stabilised prior to diamond grinding. Local spot grinding is not recommended and is otherwise going to be very expensive for just mobilising the machine.

(vi) The slot/pits are cleaned carefully and dried out if moist. This is done by sand blasting followed by air blasting. The slot is checked by wiping a hand along the slot walls and bottom. Laitance or dust adhering to the hand would indicate that further cleaning is necessary.

(vii) The crack or joint is caulked at the bottom and sides of the slot to keep patching material from entering the crack or joint and build bridges across the crack or joint.

(viii) The dowel is covered with debonding agent such as form oil or grease to allow slide movement within the hardened patch. No oil or grease shall fall onto any of the slot surfaces because it would not allow the patching material to bond to the slot and could cause the patch to fail. Placing a sleeve over the dowel is not recommended because inherent looseness could cause the dowel to socket and fail.

(ix) The dowel is prepared with non-metallic expansion end caps, a plastic foam or filler board joint reformer in the middle and non-metallic chairs. Retrofitting dowels are the same as those used in the pavement with a few modifications. Dowels mostly used are round mild steel bars not less than 450 mm long. Depending on the slab thickness, the dowel diameter is 32 mm to 36 mm. (Ref: IRC:58). Before applying form oil or grease the dowels should be epoxy coated over the entire surface including the ends to prevent corrosion and joint lock-up.

(x) A resin coat is applied to the slot walls and a resin mortar layer to the slot bottom before placing the dowel horizontally, if the patching mix is resin mortar.

(xi) The dowels in the slots are inserted so that the chair legs are in the saw-cut kerfs at

the bottom of the slot. In this position, the dowel will be aligned in the pavement middle line, parallel to the pavement surface. The joint reformer should be over the joint or crack with half-length dowel on each side. The legs and sides of the chairs should be smug against the slot walls to keep the dowel from moving during placement of the patch material.

(xii) The slot is filled with resin or fast track concrete mortar which attains minimum compressive strength of 10 MPa within 3 hours. Compact with a spud vibrator around the dowel without hitting it.

The patch mix shall have thermal properties similar to concrete and have little or no shrinkage. It shall set and develop strength quickly to allow traffic as soon as possible (32 MPa minimum).

- Compressive Strength : 40 MPa (minimum) after 28 days (IS:516)
- Bond (Shear) Strength : 7 MPa (minimum) after 28 days

(xiii) A curing compound is applied.

(xiv) The road can be opened to traffic when the patch material has gained strength of atleast 32 MPa. The pavement is then finished with diamond grinding.

11.1.3. The method of placing retrofit tie bars across longitudinal cracks is similar to the above, except spacing shall be 450-600 mm depending on thickness of slab.

11.2. Slab Lifting or Jacking

11.2.1. This repair method consists of raising sunken slabs to the level of adjacent slabs by lifting or pressure grouting beneath the panel.

11.2.2. The first method comprises the following tasks:

(i) A full depth saw cut is made along longitudinal joint(s) to separate the slabs to be raised from the adjacent panels

(ii) Holes suitably sized are drilled lifting into the slab at positions to fit the lifting frame

(iii) The hydraulically operated lifting frames are positioned transversely with lifting bolts centred over the lifting holes

(iv) Threaded female sleeves are fixed into the lifting holes with resin grout or mortar

(v) The lifting bolts are screwed into the threaded sleeves

(vi) A level reference datum across the slab to be raised, is established.

(vii) The slab is raised to the required level slowly by operating hydraulic jacks at each corner of the lifting frame

(viii) The void is filled beneath the slab with fast hardening cement grout

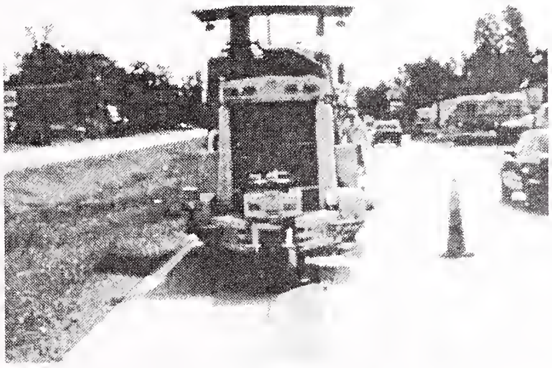
(ix) Traffic is opened only after the minimum required curing period

11.3. Reinstate the Evenness and Skid Resistance (Diamond Grinding)

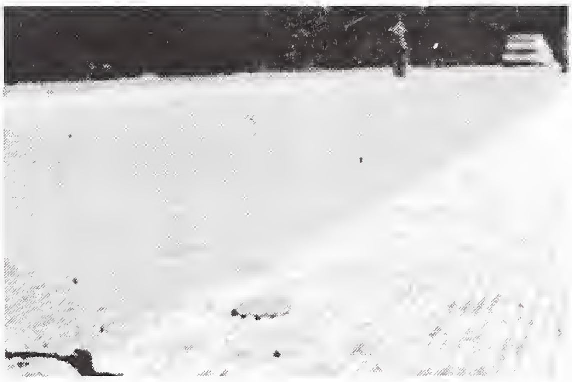
11.3.1. Removing bumps and reprofiling the surface of concrete pavements by means of diamond grinding improves the surface evenness and decreases the severity of dynamic or impact loads from heavy vehicles. Impact loads occur as trucks bounce vertically on their suspension system while travelling across bumps or dips in the road surface. Greater vehicle bounce increases tensile stresses in the slabs and consequently decreases the life of the pavement.

11.3.2. Diamond grinding also smoothes out roughness from warped or curled slabs and faulted slabs and removes patching unevenness.

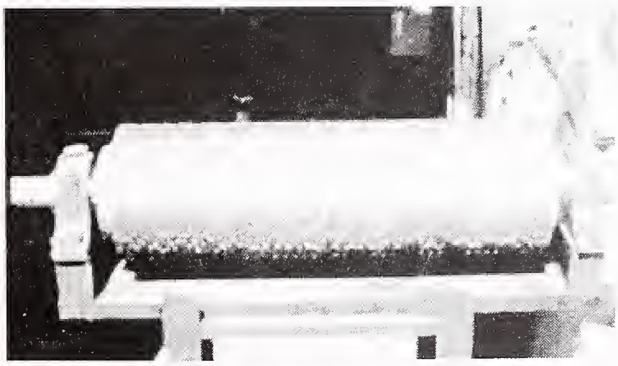
11.3.3. Diamond grinding removes a thin layer of concrete from the surface of the pavement. It is performed in the longitudinal direction with specially designed self propelled equipment that uses gang-mounted diamond saw blades on a shaft or arbor to cut through bumps and irregularities in the concrete. The width of the shaft (cutting head) is typically in the range of 900 - 1200 mm. Spacing of the blades is based on the hardness of the aggregate in the existing concrete. **Fig. 11.2** shows different steps of diamond grinding.



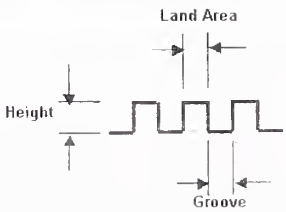
a) Self Propelled Grinding Machine



c) Diamond Ground/Grooved Surface



b) Cutting Blades Mounted on Shaft/Arbor



	Range of Values, mm	Hard Aggregate, mm	Soft Aggregate, mm
Grooves	2.0 – 4.0	2.5 – 4.0	2.5 – 4.0
Land Area	1.5 – 3.5	2.0	2.5
Height	1.5	1.5	1.5
No. Grooves per meter	164 – 194	175 – 194	164 – 177

d) Range of Groove Sizes

Fig. 11.2. Diamond Grinding

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11.3.4. In essence, the function of diamond grinding equipment is similar to that of a common wood plane. The saw blades shave off the fault or bump and the rear wheels follow behind in the smoothened path.

11.3.5. Diamond grinding equipment is used for spot correction of bumps and irregularities exceeding the acceptance limits in new construction and is also used to remove bumps from old pavements with roughness problems. The equipment may be smaller for new pavement bump grinding. This is a less costly procedure than laying a bituminous overlay and can be executed more rapidly when the machine is available locally. It should extend the service life of concrete pavements in fair to good condition by 8 to 10 years.

11.3.6. Cutting bumps by diamond grinding comprises the following tasks:

(i) The bump is contoured on the slab surface by means of a straight edge
(ii) The area is marked with coloured chalk
(iii) Bump cutting is proceeded in the most appropriate longitudinal direction checking the depth cut with the straight edge until the bump is removed
(iv) Saw slurry and debris are removed from the slab surface, by washing with water jet
(v) Slab surface is retextured

11.3.7. Diamond grinding may remove a thin layer of slab and slightly decrease the slab thickness. However, the benefit of getting an even surface and decreasing dynamic loads more than offsets the slight thickness reduction and positively affects structural performance and service life. **Table 11.1** may be reffered for limiting values after diamond grinding.

Table 11.1. Limiting Values after Diamond Grinding
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Sr. No.	Roughness Index	AVERAGE DAILY TRAFFIC (ADT)		
		ADT > 10,000	10,000 > ADT > 3,000	ADT < 3000
1.	IRI (m/km)*	2.5	3.0	3.5
2.	BI (mm/km)	1800	2200	2560
3.	General Application	Expressways, Airport Runways	National and State Highways	Other Important Roads

11.4. Diamond Grooving

11.4.1. Grooving generally provides the best treatment against aqua-planing on high speed expressways. It is like grinding cut with diamond impregnated blades or cylinder rings as shown in **Fig. 11.2** except the grooves which are usually cut in a transverse direction, are a little deeper (3 - 6 mm) and set further apart. Typically 3 - 6 mm deep x 3 - 4 mm wide with a distance of

20 mm to 25 mm between centre lines. Grooving is intended to help water expulsion under tyres. This treatment shall be considered on pavements that have exhibited a significant number of wet weather accidents (usually on curves or at junctions). (Refer **Fig. 11.2).**

11.4.2. The arbor/head width can be substantially larger considering the larger spacing between the blades. Longitudinal grooves produce less noise than transverse grooves, however, they help raising water spray trails of splash. In Indian conditions with high rainfall and slow moving vehicles transverse grooves should be preferred.

11.4.3. Surface grooving comprises the following tasks:

(i) All joints shall be effectively sealed against ingress of sawing slurry

(ii) Sawing slurry is prevented from entering surface water drains

(iii) The surface is textured by sawing randomly spaced grooves 3 mm wide by at least 4 mm deep

(iv) Deposits of slurry are flushed and removed from the pavement surface

11.4.4. Grooves shall not be cut within 150 mm of the outside edge of the slab and longitudinal joint(s).

11.5. Milling Procedure

11.5.1. Milling is only recommended as a procedure for the preparation/treatment of a concrete surface for receiving a bonded overlay. Standard milling machines with 300 mm or 450 mm wide cutting heads have proven efficient and economical particularly when used for large areas, such as full lane-width repairs.

11.5.2. The milling operation results in a rounded pit. The borders shall be made vertical by sawing or jack hammering or chiselling.

11.5.3. The advantages of the mill procedure include the following:

(i) It is efficient and economic for large areas

(ii) It leaves a rough surface that promotes bonding of the patch

11.5.4. This procedure has the following disadvantages:

(i) For repair areas shorter than 0.09 m^2, the smallest milling head results in a patch larger than needed

(ii) Milling may cause spalling of border edges

(iii) The pit edges perpendicular to the milling operation (and traffic direction) are rounded. These edges shall be made vertical by chiselling or cutting

11.5.5. When cold-milling is used, a secondary cleaning should follow to ensure the removal of dust and particulate material from the milling operation. Secondary cleaning can be done with sand blasting, water blasting, sweeping or air blowing equipment. This should be accomplished immediately prior to applying the bonding grout.

Milling procedure and finish are shown in **Fig. 11.3.**

(a) Milling Machine. (b) Finish produced after milling

Fig. 11.3. Milling Procedure

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11.5.6. Shot blasting is performed by a self contained mechanical unit that will cause no dust or particulate problems. The machine is capable of removing all surface contaminants, except some difficulty is encountered in removal of asphalt concrete or asphalt cement. The machine will throw abrasive metal shot at the surface in a contained cleaning head. The particulate matter and dust created by the operation is also picked up and discharged. The average depth of removal for this equipment is about 3 mm. Care shall be taken when using shot blasting equipment, that the shot does not penetrate the joint. It is recommended that a backer rod be installed in all open transverse joint grooves prior to the shot blasting operation to avoid penetration of shot that could eventually cause compression failures. Depending on the efficiency of the vacuum attachment available on the equipment, secondary cleaning may not be necessary after this procedure, but it is highly recommended.

11.6. Concrete Overlays

11.6.1. General:

If the existing rigid pavement is structurally weak based on the prevailing traffic or the wearing surface needs improvements in riding quality an overlay over rigid pavements is generally laid as per IRC:SP:17 "Recommendations About Overlays on Cement Concrete Pavements". There

are the following main types of overlay:

(i) Partially bonded rigid overlay over cement concrete slab
(ii) Un-bonded rigid overlay over cement concrete slab
(iii) Fully bonded rigid overlay over cement concrete slab
(iv) Cement concrete overlay over bituminous pavements, as per IRC:SP:76
(v) Bituminous overlay over cement concrete slab, as per IRC:SP:17

Family of concrete overlays are given in **Fig. 11.4.**

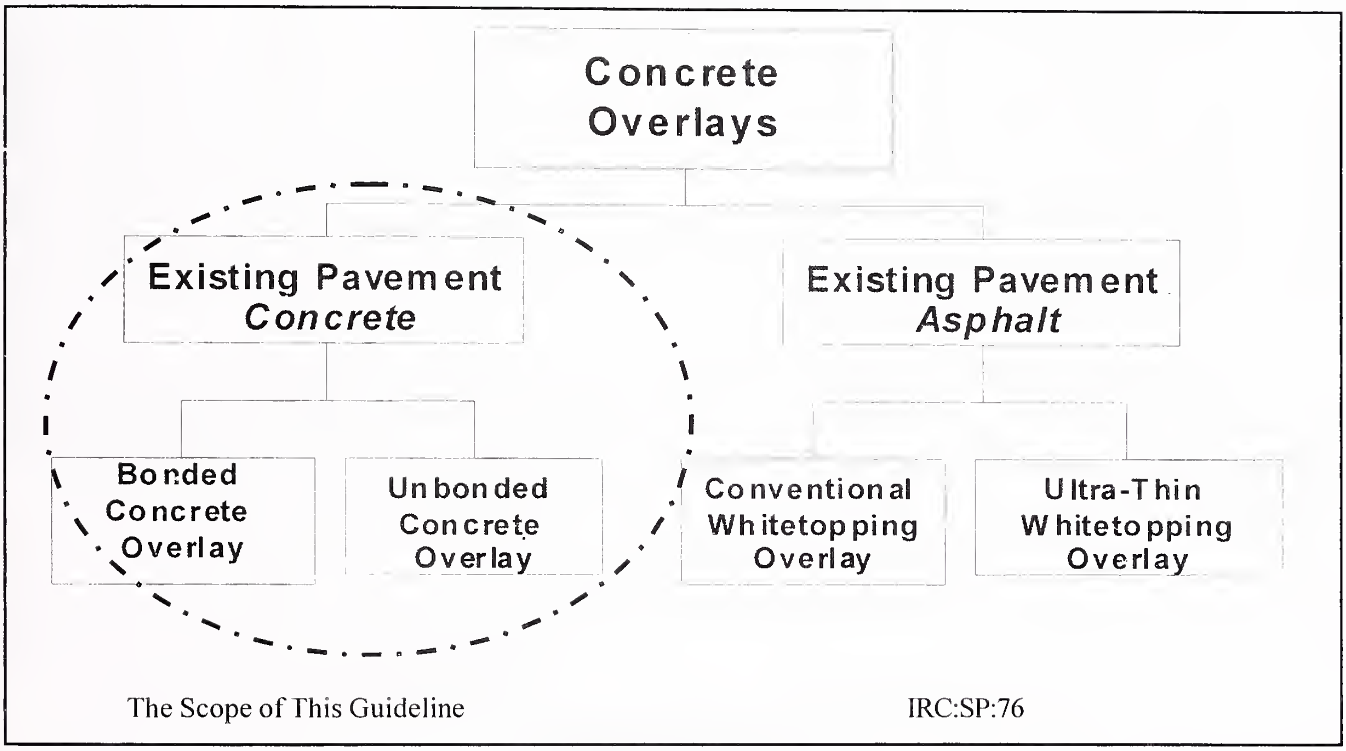


Fig. 11.4. Shows the Family of Overlay Concrete

11.6..2. Partially bonded overlay: For partially bonded overlay, the concrete pavement should be cleaned of any loose or extraneous matter, given a detergent wash @ 1 kg/10 sq.m. along with scrubbing with wire brush to remove oily and greasy materials. Subsequently the whole surface is flushed with water to remove all traces of the solution and other dust particles. Partially bonded overlay over rigid pavement is designed as per the formula given below, with matching the joints in top PQC with those in existing PQC layer:

$$h_o = (h_m^{1.4} - C\ h_e^{1.4})^{1/1.4} \qquad \text{(Eq. 11.1*)}$$

Where,

h_o = thickness of concrete overlay, cm
h_m = thickness required for the monolithic slab needed for the projected traffic as per IRC:58, cm
h_e = thickness of existing concrete pavement, cm
C = pavement condition factor, as per **Table 11.2.**

Typical Application of Partially Bonded Overlays are: for the treatment of "slightly cracked" concrete pavement.

Table 11.2. Pavement Condition Factor as per Different Categories of Distress

S No.	Length of Crackin m per 10 sq.m.	Category	Condition Factor, C
1.	0 - 1	Sound	1.00
2.	Exceeding 1-2.5	Slightly cracked	1.00
3.	Exceeding 2.5- 5.5	Fairly cracked	0.75
4.	Exceeding 5.5 -8.5	Moderately cracked	0.55
5.	Exceeding 8.5 - 12.0	Badly cracked	0.35
6.	Exceeding 12.0	Very badly cracked	0.25

* Further guidance may be taken from IRC:SP:17

11.6.3. Un-bonded overlay: Generally consists of a thick concrete layer (125 mm or greater) on top of an existing concrete pavement. Uses a separation interlayer to separate the new and existing concrete surface as per **Fig. 11.5.** At least 100 mm bituminous separation layer of bituminous macadam or (leveling course grading) may be adopted.

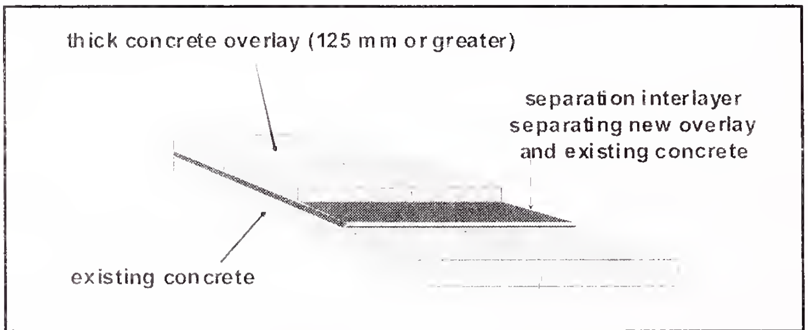


Fig. 11.5. Unbonded Concrete Overlay

The optimum thickness separation interlayer prevents distress reflecting into the overlay as shown in **Fig. 11.6.**

Typical applications of Unbonded Concrete Overlays are:

(a) for treatment of the pavements having little or no structural life remaining
(b) pavements displaying extensive and severe durability distress
(c) medium to heavily trafficked roads
(d) treatment for pavements over very weak or wet subgrade

For an unbonded overlay, rocking slabs shall be rectified, exposed sub base properly compacted and gap may be filled with coated bituminous macadam having 2.5% - 3% binder content or grouted with bitumen at the rate of 30 kg per 10 sq m. Cracks are properly cleaned and sealed properly with bituminous materials.

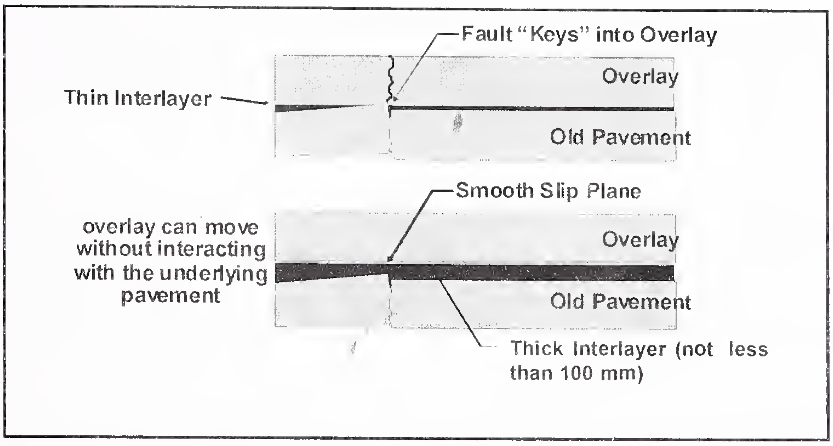


Fig. 11.6. Effects of Separation Inter Layer Thickness

An un-bonded overlay over rigid pavement is designed as per the formula given below:

$$h_o = (h_m^2 - C\ h_e^2)^{1/2} \qquad \text{(Eq 11.2*)}$$

* Further guidance may be taken from IRC:SP:17

Where,

h_o	=	Overlay thickness, cm
h_m	=	Thickness of monolithic slab, cm
h_e	=	Thickness of existing PQC
C	=	Condition factor

11.6.4. Fully bonded overlay: Generally consists of a concrete layer (150 mm or more) on top of an existing concrete surface. Specific steps are taken to bond the new concrete overlay to existing concrete as shown in **Fig. 11.7.**

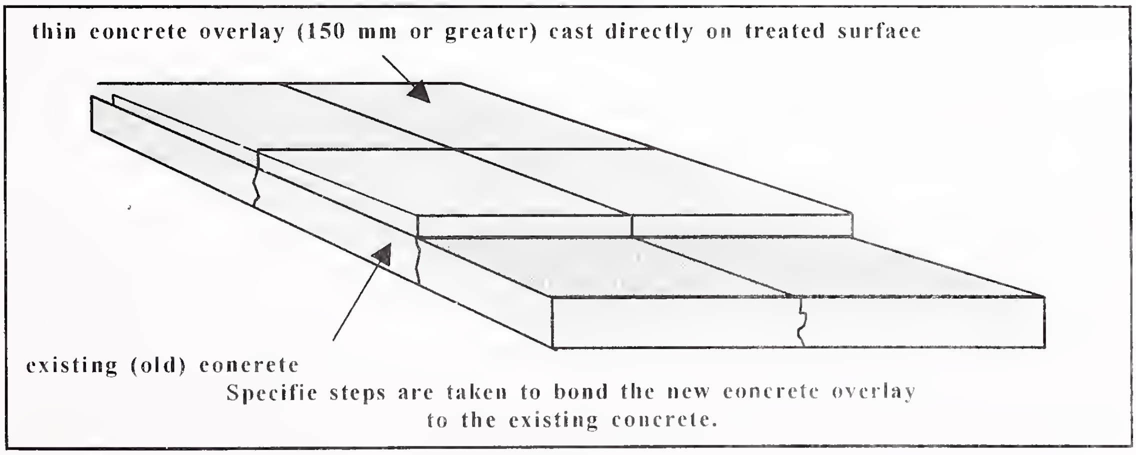


Fig. 11.7. Bonded Concrete Overlay

Bonded overlays are suitable over sound uncracked concrete pavement.

Typical applications for a bonded overlay are:

(a) to correct surface problems relating to wear or loss of skid resistance
(b) to repair damage caused by chemical spills
(c) to improve load carrying capacity

Bonded overlays need to be used with great caution, as they are not suitable over moderately or badly distressed pavements or over concrete with reactive aggregate problems or over poor subgrade.

All treatments for the preparation of the existing slabs as specified for partially bonded overlay are also applicable to fully bonded overlays. Besides this, all bond-preventing materials such as joint sealing compound, bituminous materials used for repair, paint marking, greasy and oily marks etc. should be meticulously removed. Where ever necessary, light chiseling to scarify the surface for effective bond and to remove loose materials at the surface may be done. This treatment should be followed by acid etching @ 4 kg/10 sq.m in two applications. The surface is finally flushed with water to remove all traces of acids. On the saturated surface dry slabs, bonded rigid overlay should be laid immediately after applying a thin layer (about 1 mm) of 1:1 cement sand paste/slurry as bonding medium. Shot blasting the existing surface without using grouts reportedly gives the best results (Ref: Research University of Texas, USA). For more details separate guidelines be referred. It has been the experience that fully bonded overlays with passage of time end up with partial bond. Fully bonded over lay may be designed as per the formula given below:

$$h_o = (h_m - h_e) \qquad \text{(Eq. 11.3*)}$$

* Further guidance may be taken from IRC:SP:17

11.6.5. Additional precautions for concrete overlays:

(1) In high rainfall areas, particularly where the drainage is not satisfactory and/or on pavement carrying very heavy traffic of more than 1500 commercial vehicles per day, mild steel reinforcement at the rate of 3 kg/sq.m should be provided in fully bonded and partially bonded overlays. Mild steel reinforcement mesh @ 3-6 kg/sq.m may also be provided in overlay across cracks in existing pavement.

(2) Mild steel shear pegs, if required, may be provided. A mild steel bar mesh, extending 500 mm on either side of the crack distressed portion may also be embedded at mid-depth in the concrete overlay. Joints in the overlay may be matched with those in the existing pavement both in type and location. Extra care may be taken to ensure that all edges and corners of the concrete slabs are fully coated with the cement slurry. This is particularly important as these regions are more susceptible to warping as well as initial differential drying shrinkage stresses and failure of bond in bonded concrete.

(3) Efforts shall be made to minimize evaporation of water from the top surface either by sprinkling water after 10-12 hours of laying concrete slabs and also by providing tentage at lower height with one end closed for avoiding wind tunnel effect to minimize plastic shrinkage. Addition of 0.2% fibres reduces the width of cracks if any, in case of concrete overlays. Casting of slabs from 1 am to 4 am in the early morning, may

develop shrinkage cracks due to high warping stresses, if proper precaution regarding the covering of the PQC slabs with proper arrangements are not taken. These cracks which are noticed after 24 hours of laying slabs, shall be immediately filled with dry silica fume powder, fly ash and cement using small quantity of water by application with brush. This type of treatment may be used for cracks of width less than 6 mm. These pavements after repair shall be covered with wet jute sheet (with minimum water).

11.7. Rehabilitation of Soft Earthen Shoulders

11.7.1. Shoulders should provide lateral support to the edges of the pavement, be of sufficient width and strength to support the parking of heavy vehicles under all weather conditions, shed off water, be durable and protect the lateral sub-drainage to the pavement below. Soft soil shoulders cannot comply with such requirements.

11.7.2. However on many of the National and State highway projects the earthen shoulders are constructed using fine soils which comply with the specifications for sub-grade but are easily eroded and worn away by heavy vehicles parking. The protection of lower side shoulder of super elevated portion requires special treatment or stabilisation to withstand the cumulative run-off from both carriageways.

11.7.3. A report recommending the turfing or upgrading of the soft earthen shoulders is provided in Appendix D for the information of designers and maintenance engineers. Three options are given, 1) turfing, 2) using a trafficable soil gravel mixture and 3) brick on edge.

12. REPAIR MATERIALS

12.1. General

12.1.1. Repair materials should have short setting time and develop strength fast enough to allow reopening of the lanes to traffic. In high traffic corridors the sections to be repaired can only be closed to traffic for a few hours. Lane closure of 6 to 24 hours is considered optimum. In USA, Early Opening to Traffic (EOT) rehabilitation strategy is being used these days by many State DOTs. Portland Cement Concrete used in these applications is expected to become strong enough to carry traffic within 6 to 24 hours after placement. Rigorous requirements for mix design and strength are stipulated for EOT concrete applications. The uses of such concretes are bound to increase in future because with increasing traffic levels, only limited duration lane closure for repair is possible. Appendix-B gives some of the locations with relevant details from USA where EOT concretes have been used. This type of concrete is just emerging and durability related issues of such concretes are not fully settled. A more cautious approach is recommended to be followed in India.

Para 12.3 of the guidelines briefly gives some details for such fast track concretes. Specialist literature like NCHRP report 540 "Guidelines for Early-Opening-to Traffic Portland Cement Concrete for Pavement Rehabilitation" may be referred to, if interested.

12.1.2. Repair materials may be classified under three general types:-

(a) **Cementitous** – Generally comprising of a Portland cement, gypsum or magnesium phosphate specially formulated to provide opening times of 2 – 8 hours or 20 – 24 hours (Ref: NCHRP Report 540).

(b) **Polymer based** – Generally comprising of an epoxy, methyl methacrylate, polyester-styrene or polyurethane based resin mixed with aggregates and a catalyst (hardener) formulated to provide opening times 6-8 hours.

(c) **Bituminous** – Comprising of a bituminous binder and aggregate mix, these materials are generally considered for making a temporary patch only.

12.1.3. The polymer based resins are preferably used for small areas and volumes of repair. An exception is patching of dowel slots where cement mortar is preferred to match the thermal properties of the surrounding concrete. The rapid setting cement based materials are used for larger areas and volumes to minimise differential thermal behaviour and minimise costs.

12.1.4. The minimum strength to allow traffic is 32 MPa (150 mm cube compressive strength).

Note: It is necessary to remind that the several publications by FWHA and ACPA (USA) mentioned in Appendix-A report compressive strengths according to ASTM C 39 which tests cylinders (150 mm dia x 300 mm) whereas in India the standard method for determining and reporting the compressive strength (IS:516) uses cubes (150mm). The target cube compressive strength = cylinder compressive strength/0.80. (Cylinder having length: diameter ratio = 2).

12.1.5. The repair materials shall be designed and tested in the laboratory and tested on the road so to conform to the manufacturers specifications.

12.1.6. The **Table 12.1** gives a guide to the selection of suitable patching material according to the size and depth of patch contemplated.

Table 12.1. Guideline for Selection of Type of Product for Repair of Common Defects in Concrete Pavements

S.No.	Type of Defect	Extent of Damage		Type of Product
		Maximum Surface Area	**Minimum Depth**	**Recommended for Trial**
1.	Full Depth Repair	All	Full Depth	Conventional Cement Concrete with additives
2.	Small Popouts	< 0.12 m²	30mm	Epoxy Mortar (1:3)
3.	Spalled Joints, Scaling	< 0.12 m², Longest Dimension not Exceeding 600 mm	65mm	Epoxy Mortar (1:3)
			75mm	Epoxy Concrete (1:8)
4.	Large Spalled Areas, Scaling	> 0.12 m², or Longest Dimension Exceeding 600 mm	30mm	Elastomeric Concrete
		> 0.5 m²	100mm	Polymer Modified Cementitious Concrete
5.	Corner Breaks	< 0.12 m²	30mm	Epoxy Mortar
		> 0.12 m²	65mm	Elastomeric Concrete / Epoxy Mortar

Note: Approval should be based on the Engineer's assessment of the trial performed on the first defect treated of each kind.

12.2. Cement Mortars for Patching

12.2.1. The cement patch mixes often use IS:269, IS:1489, IS:8112 or IS:12269 type Portland cement and also proprietary cement that gain strength very quickly. To decrease the

water-cement ratio a water reducing admixture may be required for 43/53 Grade Cement. Fast-track concrete mixes usually contain type cement IS:8112 or IS:12269, with accelerators to shorten the concrete setting time.

12.2.2. The Table 12.2 shows information on rapid-setting hydraulic binders or cementitious materials that are currently used for patching concrete pavements. Such binders often contain chloride accelerators that may cause corrosion of dowel bars. Some polymer modified cement concrete mixes may reach a compressive strength of about 28 MPa within time as given in the **Table 12.2.**

Table 12.2. Typical Time to Achieve Compressive Strength 28 MPa

S. No.	Material Category	Hours
1.	Certain gypsum and magnesium based cements	2-4
2.	Sulfo-aluminate cements	2-4
3.	Polymer modified methacrylate	2-4
4.	Polymer urethane	1-2
5.	43 Grade (IS:8112) or 53 Grade (IS:12269) = cement with non chloride accelerating admixture	4-6
6.	43 Grade (IS:8112) or 53 Grade (IS:12269) = cement with water reducing admixture	12-24

12.2.3. Some of the rapid-setting hydraulic binders are proprietary materials and in this case careful attention should be paid to manufacturers specifications. They should also be selected to match the climatic conditions that are expected during the repair work.

12.3. Fast-Track Concrete for Large Patching

12.3.1. Fast-track concrete or high early strength concrete is essential for full-depth patching when early opening to traffic is required.

12.3.2. High early compressive strength concrete (20 - 25 MPa in 24 hours) is usually obtained using Grade 43 or 53 high-early strength cement, high cement content (350 - 600 kg/m^3), lower water-cement ratios (0.3 to 0.45 by weight), well graded aggregates, extra cement and chemical accelerators. Super-plasticisers are also used to make the concrete mixture more workable during placement. Fly ash, silica fume and ground granulated blast furnace slag are sometimes used in the mix to partially replace some of the Grade 43 or 53 cement.

12.3.3. Aggregate gradation uniformity will improve concrete strength, workability, and long-term durability. Intermediate size aggregates fill voids typically occupied by less dense cement paste and thereby optimise concrete density.

12.3.4. Calcium chloride ($CaCl_2$) should not be added as an accelerator under any circumstances.

12.3.5. Insulating blankets (or other insulation measures) can also be used in the first 24 hours to help strength gain by retaining the heat of hydration. Caution shall be taken, though, to avoid thermal shock when the blankets are taken off. Thermal shock may cause premature cracking of the concrete.

12.4. Elastomeric Concrete for Patching

12.4.1. Elastomeric concrete is a polyurethane based material designed to develop early high strength and easy bonding to a variety of materials. It comprises of a modified binder, fine aggregate and glass fibre. It hardens very quickly. It is relatively more expensive than normal epoxy mortar formulations but offers saving in the depth of the patch. Refer **Table 12.3.**

Table 12.3. Physical and Performance Properties of Elastomeric Concrete

Property	Minimum Requirement	ASTM Test Method
BINDER ONLY		
Gel time, minutes	5 minimum	--
Tensile Strength, (MPa)	10 minimum	D 638
Elongation at break, %	200 min	D 638
Hardness Type D durometer, points	90 +/- 3	D 2240
COMPLETE BINDER–AGGREGATE MIXTURE		
Tensile strength, (MPa)	4.1	D 412 (mod)
Elongation at break (Ultimate), %	25 min	D 412 (mod)
Hardness Type D durometer, points	50 Shore D max	D 2240
Compression defection properties - stress (MPa), 5% deflection - resilience, 5% deflection	 5.5 min/8.7 max 70 min	 D 695 D 695 (mod)
Impact ball drop @ 29°, no cracking (Joule)	> 13.5	
Adhesion to concrete (MPa) Dry Bond Wet Bond	 2.4 minimum 1.4 minimum	D 3029 (mod)

12.5. Resin Mortars for Patching

12.5.1. Commonly used resin binders are epoxy, urethane and methacrylate polymers. Resin binders should be selected for the climatic conditions that are expected during application work.

12.5.2. The various components of resin system must be kept in tightly closed containers.. Smoking may not be allowed in the vicinity of the resins. After expiry of shelf-life, material shall not be used without rechecking its quality through laboratory tests. The following handling practice for resin materials and mixes is required:

(a) Working in a well-ventilated area (in case of laboratory tests)
(b) Storing the resin materials below eye level
(c) Using disposable containers, equipment and gloves, wherever feasible
(d) Using safety goggles when handling resin compounds
(e) Temperature of mix shall not be more than 60^{0}C.

12.5.3. There is no solvent material for removing set resin-formulations. However unset/ partial set resin from containers may be cleaned by:

(a) Mixture of equal proportions of ethyl alcohol and benzene
(b) Mixture of equal proportions of ethyl alcohol and toluene
(c) Toluene
(d) Benzene
(e) Ethyl alcohol
(f) Local soap/detergent

12.5.4. In addition to these guidelines, manufacturers recommendations for mixing, patching and curing should be strictly followed.

12.5.5. Fine or coarse aggregates depending on the application may be used in the epoxy resin formulation. The grading of fine aggregate, which is mainly used for repair is given in **Table 12.4.** Size of coarse aggregate is maximum 25 mm. Fine sand passing 1.18 mm sieve of FM 1.0 is used.

Table 12.4. Recommended Grading or Sand for Resin-Sand Mortars

Sieve Size	Fine Sand % Passing	Medium Sand % Passing
4.76 mm	100	100
2.36 mm	100	100
1.18 mm	100	100
600 micron	95-100	50-60
300 micron	90-100	20-30
150 micron	5-20	20-30

Note: For better skid resistance hard silica, crushed stone, alumina, silicon carbide, slag etc 2 mm to 600 micron size may be used.

12.5.6. In epoxy formulations with tertiary amine as hardener, the quantity of the tertiary amine is limited between 4 gm - 10 gm per 100 gm epoxy resin for temperature range 40°C to 10°C. In resin mortars, generally one part by weight of resin formulation is mixed with 3-5 parts by weight of medium to fine sand. In case of epoxy resin concrete using larger maximum size of aggregate, the proportion of aggregate may be as high as eight (8) parts to one (1) part of resin formulation by weight.

12.5.7. The quantity to be mixed at a time should normally not exceed 2 kg because of the short pot life of the resins. The cement concrete temperature may be at least 15°C and preferably about 25°C, prior to application of the synthetic resin. Under cool weather conditions. electric heaters, for lighting 1000 Watt electric bulbs may be used in such a manner that the surface temperature stays below 40°C during the hardening period.

12.5.8. In general the compound is not heated beyond 60°C or cooled below 15°C. After applying the first tack coat on the bottom as well as sides of the prepared pit groove, the sides of the pit groove are given a second coat of resin formulation. Special care is required along the edges and at corners which are more prone to be left uncoated. For small sized work, a 20 mm hair brush may be used. Before the tack coat loses its tackiness, resin-sand mortar or concrete, depending on the depth of the patch, is placed in the grooved recess with the help of a trowel. For patches thicker than 20 mm, the sand is combined with a coarse aggregate having maximum size not greater than one –third the thickness of the patch. If the patch is deeper than 50 mm, it is built up in two or more layers to reduce heat build up and subsequent thermal contraction. Full compaction is ensured by rodding. A light layer of the dry sand should be spread over the finished patch. After application, the resin patch is kept at a temperature of 30°C - 40°C to accelerate curing by infrared lamps.

12.5.9. The use of polyester resins as bonding media between old and new concrete is generally ruled out on account of their high susceptibility to moisture. **Table 12.5** gives the typical formulations and properties.

12.6. Bituminous Materials for Patching

12.6.1. The use of bituminous mixes is very exceptional. Experience with bituminous binders for patching concrete slabs is not satisfactory and they are generally not recommended except for use as a temporary patch in emergency conditions when other more suitable materials are not available at site.

12.7. Joint Sealants and Backer Rods

12.7.1. The following section shall also be read in conjunction with Chapter 6.

Table 12.5. Typical Values of Different Properties of Resin Formulations and Mortar

S.No.	Property	Epoxy
(a) RESIN FORMULATION		
1.	Coefficient of thermal expansion 10^{-6} cm / °C	23 – 25
2.	Viscosity, c' poise at 27°C	4,000 – 10,000
3.	Linear shrinkage, max. %	0.1
4.	Specific gravity, Min. Max.	1.05 1.20
5.	Pot life, minutes Varies with accelerator used, at 25°C 30°C 35°C	 90 minutes 60 minutes 45 minutes
6.	Storage life	At least 12 months
(b) RESIN MORTAR MIXTURE		
1.	Moisture susceptibility	Slightly susceptible
2.	Compressive strength 1:3 to 1:6 with fine and medium sand, kg / cm²	350 – 1000 (at 2 days age)
3.	Tensile strength with fine sand (1:3 to 1:4), kg/cm²	80 – 100 (at 2 days age)
4.	Flexural strength with fine sand (1:3 to 1:4), kg/cm²	400 – 500 (at 7 days age)
5.	Bond strength both with fine and medium sand (1:3 to 1:6), kg/cm²	25 – 45 (at 2 days age)

12.7.2. Joint sealants can be divided into two broad categories:

(1) Liquid (Field moulded) sealants which are poured or gunned into the joint

(2) Preformed factory moulded seals which are compressed into the fresh concrete or hardened joint

12.7.3. The field moulded sealants may be cold or hot poured and further categorised under the following three types:

(1) Thermoplastics, Hot Applied: Usually black in colour and include materials such as asphalts, rubber asphalts, coal tars and rubber tars

(2) Thermoplastics, Cold Applied : Include acrylics and vinyls as basic material

(3) Thermosetting, Chemically-Curing Compounds : Usually one or two component systems and include polysulphide, silicone and polyurethane and epoxy based materials

12.7.4. There are many liquid joint sealant materials available in India, but each has its distinct characteristics, such as:

(a) preparation time
(b) workability/ease of placement
(c) curing time
(d) adhesiveness
(e) cohesiveness
(f) resistance to softening and flow
(g) flexibility
(h) elasticity
(i) resistance to aging and weathering, and resistance to weathering

12.7.5. The **Table 12.6** summarises the specification and relative costs of commonly used types of cold - and hot poured liquid (field moulded) sealants. This table also shows the design extension, or the extension that the installed sealant can withstand without being damaged and the shape factor. Further description and guidance is provided in **Appendix–C** and IRC:57.

Table 12.6. Various Specifications for Sealant Materials
(Ref: 1.12, Table 1 and IRC:57)

Sealant Material	Applicable Specification		Design Extension	Shape Factor (Depth/Width)	Relative Cost (Ref: CRRI)
	BS/BIS	US			
PVC/Coal Tar		ASTM D 3406	10% - 20 %	1 : 1	3.0
Rubberised Bitumen	IS:1834	ASTM D 1190		1.25:1	3.5
Polymeric Asphalt Based		AASHTO M 173 ASTM D 3405 AASHTO M 301 ASTM D 6690 Fed SS-S-1401C	15% - 20%	1:1 Overbanding Recommended	3.5
Polysulphide	BS:5212 IS:11433 (Part-1) 1985	Fed SS-S-200E AASHTO M 282	10% -25%	1.25:1	4
Silicone Polyurethane	BS:5212	ASTM D 5893 Fed SS-S-200 E	30% - 50% 10% – 20 %	1:1	7 6
Other Specifications/ Test Methods Found in IRC/ NHAI Documents		ASTM D 113 ASTM D 3583			

12.7.6. A primer shall be used according to the sealant manufacturer's recommendations for improving the adhesion between the sealing compound and old concrete.

12.7.7. A variety of backing rods and tapes are available in the market conforming to different specifications. Backer rods manufactured from material conforming to ASTM D 5249 Standard Specification for backer material for use with Cold and Hot Applied Joint Sealants in PCC pavements is recommended. Backer rods shall be oversized (by 25%) relative to the joint width so to provide firm resistance when applying the sealant, and also to present percolation of sealant in the crack underneath.

12.7.8. For all materials, the manufacturers recommendations should be carefully considered and followed. Field adhesion tests to the joint substrate performed in accordance with the manufacturers recommendations with their technical representative present is recommended. Warranties against adhesion and cohesive failure should be considered whilst preparing the contract documentation.

12.7.9. Preformed compression seals are made from neoprene rubber and have an internal web structure so that the material remains compressed in the joint. The joint seal shall conform to ASTM D 2628 with the properties as given in **Table 12.7** (IRC:57).

Table 12.7. Requirements for Preformed Compression Seals

S.No.	Description	Requirements	ASTM Test Methods
1.	Tensile Strength, min.	13.8 Mpa	D412
2.	Elongation at break	min. 250 %	D412
3.	Hardness, Type A durometer	55 +/- 5 points	D2240
4.	Oven aging, 70 h at 100°C Tensile strength loss	20 % max	D573
5.	Elongation loss	20 % max	
6.	Hardness Change Type A durometer	0 to +10 points	D471
7.	Oil Swell, ASTM Oil 3, 70 h at 100°C weight Change	45 % max	D1149
8.	Ozone resistance 20% strain, 300 pphm in air, 70 h at 40°C	No cracks	D2240
9.	Low temperature stiffening, 7 days at -10°C Hardness Change type A durometer	0 to + 15 points	
10.	Low temperature recovery, 22h at -10°C, 50 % deflection	88 % min	D2628
11.	Low temperature recovery, 22h at -29°C, 50 % deflection	83 % min	D2628
12.	High temperature recovery, 70h at 100°C, 50 % deflection	85 % min	D2628
13.	Compression, deflection, at 80 % of normal width (min)	613 N/m	D2628

12.8. New Materials

New concrete repair materials based on chemical formulations have surfaced in the local market in India. These are proprietary items. Proprietary firms are advocating an effective and fast result, particularly in the area of minor crack repairs. The present guidelines do not make any recommendations about the same. Highway Agencies may consider using them on selective basis after being satisfied about them and reporting about their performance to IRC for evaluation and wider publication after acceptance.

13. TOOLS AND PLANT

13.1. General

13.1.1. A list of equipment that will be generally needed for various types of repair work on cement concrete pavements is given below. In addition, it may be necessary to have mobile units located at key places so that the repair work may be centralised and handled expeditiously. For this purpose, a truck wherein a small hand operated drum/jiffy mixer, vibratory tamping equipment, and some small essential tools are provided, can be very useful.

13.2. List of Tools and Equipment for Different Types of Repair

13.2.1. For joint resealings

(i) Plough for removing old sealant
(ii) Wire Brushes
(iii) Sand blasting equipment, air compressor with in-line filters to trap oil and water, hoses, 6 mm venturi- type tube
(iv) Broom and/or power vacuum
(v) Backer rod installation tool/roller wheel
(vi) Sealant applicator equipment (and mixing head for two component systems)
(vii) Pail mixer
(viii) Plastic measuring beakers
(ix) Masking Tape
(x) Trowels
(xi) Personal safety equipment (ie: gloves, masks, safety vest first air box etc.)

13.2.2. For crack repair and cross-stitching

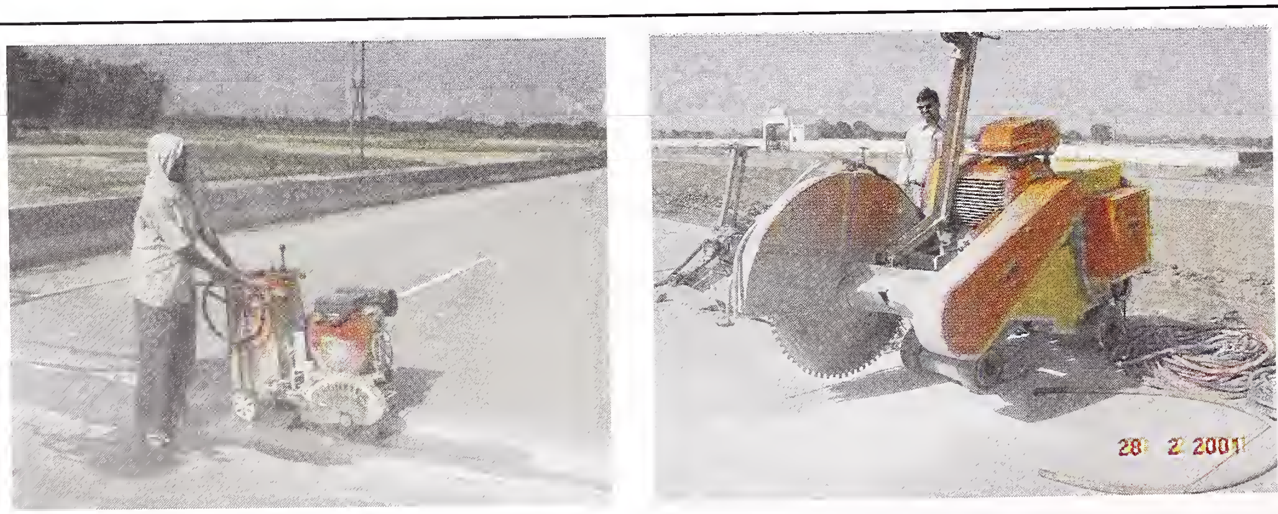
(i) Random crack saw (130mm dia diamond blades)
(ii) Vertical spindle router (belt drive)
(iii) Single headed scabbling tool or router (crack cutter)
(iv) Template
(v) Small portable generator
(vi) Portable air compressor Min. 71 litres/sec at 0.55 N/mm^2
(vii) Rotary impact hammer drill
(viii) Trowels and floats
(ix) Personal safety equipment (gloves, masks, safety vest first air box etc.)

13.2.3. For spall repair

(i) Concrete saw (170 mm to 250 mm dia diamond blades for large patches, 130 dia for small patches)
(ii) 170 to 250 Portable air compressor Min. 71 litres/sec at 0.55 N/mm²
(iii) Electric chisel
(iv) Club Hammer (4 kg)
(v) Cold Chisels
(vi) Pail mixer, hand held or paddle wheel
(vii) Mixing pails, small
(viii) Plastic measuring beakers
(ix) Masking Tape
(x) Hand tools, shovel, trowels, tampers and screeds
(xi) Personal safety equipment (i.e. gloves, masks, safety vest etc.)

13.2.4. For partial/full depth and whole slab replacement repairs

(i) 50-60 H.P. diesel or petrol mobile concrete saws (smaller machine may be suitable for limestone aggregate concrete)
(ii) 750 – 1000 mm dia. Diamond saw blades for full depth repair and 300 - 450 mm dia Diamond saw blades suitable for partial depth cutting, **(Fig. 13.1).**
(iii) Portable air compressor min 118 litres/sec at 0.55 N/mm and concrete breaking tools /jack hammer (14 kg)
(iv) Heavy duty wire cutters or bolt croppers



(a) 450 mm Dia Saw suitable for Partial Depth Repair (b) 1000 mm Dia Saw suitable for Full Depth Repair

Fig. 13.1. Different Size Saws for Cutting Concrete
Equipment and tools as per IRC:43

(v) Small portable generator
(vi) Rotary drill
(vii) Club hammer (4 to 6 kg)
(viii) Cold chisels
(ix) Drilling jig or frame
(x) Welding equipment (for continoulsy reinforced slabs)
(xi) Frame for holding dowel bars in position until resin mortar hardens (jointed slabs)
(xii) Poker vibrator(s)
(xiii) Vibrating finishing beam (for leveling surface uniformly)
(xiv) Wire Tyne (for surface texturing)
(xv) Trowels, floats and arising tool

13.3. Saw Blade Selection

13.3.1. The saw blade for cutting concrete must be compatible with the output and speed of the saw, concrete strength and application.

14. PLANNING THE MAINTENANCE OPERATIONS

14.1. General Objectives

14.1.1. The general principles and objectives of highway maintenance as it particularly concerns the preservation of concrete pavements is dealt with in this section.

14.1.2. Concrete pavements generally deteriorate gradually in life (5 – 25 years) and deteriorate quicker as they approach the effective service life (30 – 40 years). Refer **Fig. 1.5** in Chapter 1. Spot repairs and restoration of isolated parts are performed to prevent or slow the overall deterioration of the concrete pavement.

14.1.3. The deterioration can affect the whole pavement structure beyond the effective service life and therefore also affect the safety and comfort of the user and the maintenance costs. Earlier intervention to restore its condition before there is significant drop in pavement quality should be the objective of the maintenance strategy. The maintenance and repair of concrete roads is therefore as essential as that of any other concrete structure.

14.2. Organisation and Management

14.2.1. The maintenance of Highway Pavements generally embraces all the activities illustrated in **Fig. 14.1.**

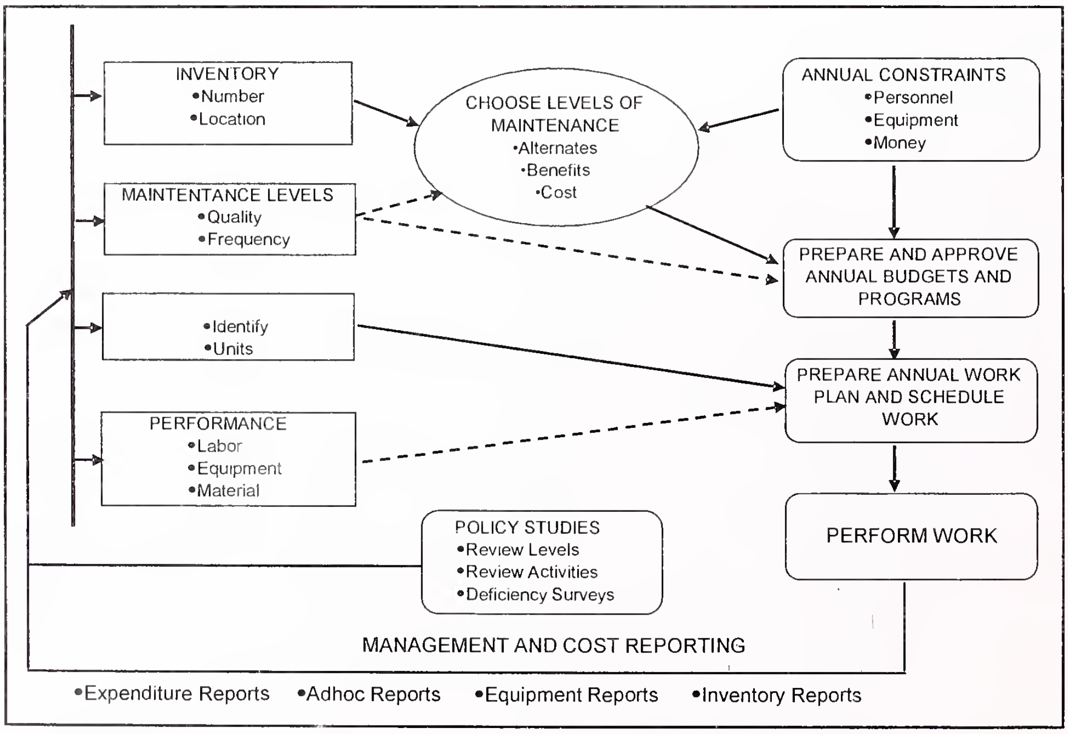


Fig. 14.1. Schematic Diagram or Maintenance Management System

14.2.2. Maintenance of a road requires proper supervision of skilled workmen who are adequately trained in various aspects of maintenance. The supervisory staff, generally known as junior engineers in this country, is therefore to be given training in various aspects of cement concrete pavement work. They should be conversant with the specifications for various types of repair works, the choice of repair, the quality control measures needed to achieve good workmanship, use and upkeep of equipment and tools and safety measures to be adopted during the maintenance operations.

14.2.3. Planning and scheduling of the maintenance operations should be given due importance. The annual renewal programme should be drawn up well in advance keeping in view the condition of the surface, prescribed renewal cycle and any improvement work carried out recently or scheduled to be taken up in the near future. It is useful for easy comprehension to depict the renewal programme on bar chart indicating the renewals carried out in the last eight years. The budgeting for maintenance expenditure should also be done well in advance and the allocation of resources to the different operations of maintenance should be finalised simultaneously. This would facilitate the field engineer to plan and implement his programme effectively.

14.3. Periodical Monitoring

14.3.1. The **Table 14.1** lists the types of formal inspections and surveys with recommended frequencies.

Table 14.1. Types and Frequency of Inspections

S.No.	Type of Maintenance Inspection	Recommended Frequency
1.	Project Preparation Survey	Performed by (or on behalf of) the Client for drawing up the scope of work for the maintenance Contract.
2.	Initial Condition Survey (Contract)	Within 28 days of taking over or signing the maintenance Contract (whichever is applicable)
3.	Safety Inspections	Not less than once a week on National and State Highways, and fortnightly on all other roads
4.	Intervention Inspection	Once a week, and on at least one occasion accompanied by Deputy Collector and DSP for controlling encroachments etc.
5.	Bridges, Culverts and Drains Inspection	On a regular basis, according to availability of qualified inspectors but not exceeding six (6) months. Note: NHAI guidelines specify three (3) months
6.	Night Inspections	Periods not exceeding six months.
7.	Annual inspections	Highway pavement condition report including settlements, deflections and roughnesscondition of facilities such as bus shelters, buildings at Toll Plaza etc.
8.	Completion Condition Survey (Contract)	Not later than 21 days prior to the Completion Date of the Contract

14.3.2. The pavement shall be periodically monitored since new distress may appear and existing distress propagate further.

14.4. Distress Identification and Classification

14.4.1. By early detection, classification and repair of defects in their initial stages the rapid deterioration of the pavement and its joints can be prevented.

14.4.2. The first step to planning a maintenance operation is the evaluation of the existing pavement in terms of its physical condition and both its functional and structural capacity. For this purpose, condition surveys should be undertaken for the visual assessment of the pavement, which would cover not only the type but also the magnitude of the distress and its location. Apart from visual surveys, pavement surface evaluation based on riding quality (i.e. road roughness) and skid resistance should also form the basis for taking maintenance decisions.

14.4.3. Necessary information about the routine maintenance needs will be readily available as the maintenance staff are expected to be continuously in touch with the physical condition of the road. However, for deciding periodic treatments and long term maintenance strategies, condition surveys carried out at a fixed frequency are a must. Keeping this in view, it is desirable that at least two condition surveys are conducted on each stretch of road every year, one before and the other after the monsoon i.e. the same frequency as with flexible pavements. Generally the condition surveys are carried out on foot because cracking and joint problems may not be discernible from a vehicle even if travelling at a slow speed. The data collected should be recorded methodically kilometer wise. It is desirable that these visual surveys are carried out by an experienced engineer at a responsible level. See Chapter 4 Proforma 4.3.

14.4.4. Based on the condition evaluation, the causes for the various defects observed should be examined in detail as discussed in Chapter 4 and a decision taken whether to initiate a particular maintenance activity, defer the same or to go in for more detailed investigations to determine the treatment/rehabilitation needs precisely. Where distress on the pavement has reached the stage of pot holing, spalling and/or the slabs are rocking under traffic which affects the smooth operation of traffic, it should be rectified straightway. For other defects like cracking, ravelling etc., the optimal strategy should be determined having regard to the various factors involved including the finances available and a decision taken whether to go in for temporary measures like sealing/ resurfacing or to strengthen/reconstruct the pavement. If the latter appears necessary, further investigations about structural deficiencies shall be taken up as mentioned in Para 4.4. In other words the planning of the various maintenance operations should be correlated and looked upon as a total system rather than each activity being considered in isolation. There can be sometimes more than one strategy to address a distress problem.

14.4.5. Once the overall maintenance plan has been drawn up, attention should be given to the proper organisation management of the whole programme including deployment of various resources, i.e. men, materials and equipment, in an efficient manner. For each maintenance activity the work at site should be carefully controlled so that the optimum output and quality are achieved.

14.5. Performance Standards for Maintenance

14.5.1. The general objective of road maintenance is to provide a clear and smooth ride so traffic may pass safely and comfortably. The performance standards define the level at which the facility is to be maintained.

14.5.2. Maintenance standards should consider the following:

(a) Traffic data (volumes and axle loadings)
(b) Surface texture
(c) Drainage condition
(d) Cracking
(e) Shoulder drop-off
(f) Slab warp
(g) Spalling
(h) Slab settlement, faulting
(i) Heave or distortion
(j) Settlements at bridge approaches
(k) Sub-base failure
(l) Joint separation
(m) Joint sealing
(n) The need to minimise traffic disruptions

14.5.3. The basis of maintenance standards set out in this Guideline are based on the following fundamentals:

(a) **Pavement surface** - The pavement surface shall be kept thoroughly clean as part of the routine maintenance program at a minimum frequency of twice a year in rural stretches and four times a year in the habited/built up stretches so to protect the concrete surface from accelerated abrasion and to prevent stones lodging in and damaging joints.

Stones and other debris on the carriageway are a safety hazard (causing broken windshields and swerving of vehicles to avoid larger debris) and damage the pavement surface. Soil and other debris accumulated beside kerbs and chute drains in median and beside barrier kerbs etc. prevents free drainage of water increasing the risk of damage under traffic.

Job Description	Criteria Extent (% sub-section length)	Location/ Side	Treatment/ Action	Type of Maintenance
Pavement cleaning (sweeping) including removal of litter rubbish and other debris	(a) Minimum twice a year, or b) When exceeding 25% in any 20 m long stretch.	All	Sweep, wash and dispose	Routine
	(b) When accumulation prevents the free drainage of water from the pavements, kerbs and channels.	All	Remove and dispose off site.	Urgent i.e. Within 2 days of detection

(b) **Cracks** – Individual cracks 3 mm wide and any other areas with extensive finer cracking shall be repaired before the rainy season to prevent infiltration of water into the foundation layers.

(c) **Settlement, Heave, Distortion, Faulting** – Correction of surface irregularities shall be scheduled when the surface deviation reaches 38 mm in a length of 2.5 m or when the riding quality is objectionable (> 4000 mm/Km). This type of defect otherwise results in poor riding quality and extra loading on the slabs which accelerates pavement deterioration. Diamond grinding shall be applied when the level difference between two slabs across a joint or cut becomes more than 4 mm.

Regular inspection below approach slabs at bridges is also very necessary to detect signs of voids under the slabs and/or springyness/pumping. Settlement of approach slab is otherwise likely to occur. Early detection and filling of voids can often prevent slab settlement.

(d) **Spalling** – Transverse spalling exceeding 100 mm in the direction of travel and more than 6 mm deep or other similar type defects which induce extra loading on the slabs and adversely affect comfort shall be repaired.

(e) **Joint Separation** – Separation between the concrete slabs exceeding 3 mm shall be filled to prevent infiltration of water into the foundation layers. Similarly separation/erosion occurring between the interface of concrete pavement and paved/ unpaved shoulder should also be filled up/repaired promptly to prevent runoff further eroding and eventually undermining the edge of the concrete pavement.

14.6. Training

14.6.1. The MoRT&H Specifications for Road and Bridges specifies the importance of building in quality assurance into the planning and execution of all the works including the pavement works.

QUOTE "The Contractor shall ensure that all the actions are taken to build in quality assurance in the planning and execution of the works. The quality assurance shall cover all stages of work such as setting-out selection of materials, selection of equipment and plant, deployment of personnel and supervisory staff, quality control testing, etc.
END OF QUOTE (Ref: Clause 105.3).

14.6.2. Training is an integral part of Quality Assurance. The Contractor should get his staff trained for the following through Seminars and Training workshops:

(i) Durable concrete pavement mix design (for partial/full depth replacement and full panel replacement)
(ii) For pavement evaluation and identification of distress/severity rating
(iii) For cleaning of joints
(iv) For priming of joint groove and installation of sealants
(v) Marking of repair boundaries, hacking out distressed concrete and refilling of concrete and epoxy concrete/quick setting cementatious materials

14.6.3. The training of staff should therefore form an essential part of the execution of any maintenance strategy. The owner of the pavement should make it mandatory to make provision in the contract/document for training of Contractors' staff so that the diagnosis of the cause and quality of the repair job is assured.

15. ARRANGEMENTS FOR TRAFFIC AND SAFETY

15.1. Traffic Control

15.1.1. Since maintenance operations involve considerable hardship, inconvenience and hazard to traffic and also hazards to maintenance workmen, all possible precautions should be taken to make safe arrangements for traffic. These include erection of barriers, signs, red flags and lights including flickering caution lights. Efforts should be made to confine work in half the pavement width at a time, leaving the other half for use by the traffic. Where this is not possible, diversion roads may have to be constructed or the traffic diverted to some other alternative routes. The maintenance operation itself can be conveniently confined to a small length at a time, say 30 m.

15.1.2. Traffic diversion shall be planned and implemented in accordance with the recommendations of IRC:SP:55 "Guidelines on Safety in Road Construction Zones". The lettering shall be legible from a speeding vehicle at 100 m. Traffic signs should be of no less than 900 mm x 600 mm in case of rectangular signs and 900 mm in case of circular and triangular signs.

15.1.3. The traffic shall be clearly warned sufficiently in advance. The appropriate warning sign to be used is the "Man at work" sign, as per IRC:67 "Code of Practice for Road Signs". If half the road width alone is available for traffic, the "Narrow Road Ahead" sign should also be displayed. If closure extends into the night or several days, the signs shall be retro-reflective by an approved manufacturer. During night in urban stretches, (and where practical in rural stretches) there should be adequate lighting with a red lantern/red reflectors. Adequate ward and watch shall be provided to prevent stealing of all the traffic control devices

15.2. Safe Working Environment

15.2.1. The safety of the worker shall also be addressed in the program. Job instructions shall include safety items that should be addressed while undertaking repairs, These should include:

(a) Use of high visibility clothing
(b) Correct lifting techniques
(c) Understanding hazardous materials used and correct mixing and application
(d) Moving vehicles outside the site
(e) Correct use and handling of plant
(f) Awareness of underground and or overhead cables and utility services
(g) Availability and general awareness of First Aid Kits

APPENDIX-A

LIST OF REFERENCES

A.1. List of IRC Publications and Indian Standards

(1.1) IRC:61-1976, " Tentative Guidelines for Construction of Cement Concrete Pavements in Hot Weather"

(1.2) IRC:77-1979, "Tentative Guidelines for Repair of Concrete Pavement Using Synthetic Resins"

(1.3) IRC:84-1983, " Code of Practice for Curing Cement Concrete pavements"

(1.4) IRC:SP:17-1997, "Guidelines for the Overlay Design (Composite Pavement Construction)"

(1.5) IRC Special Publication, 2001, "Report of the Committee on Norms for maintenance of Roads in India "

(1.6) IRC:67-2001, " Code of Practice for Road Signs"

(1.7) IRC:SP:55- 2001, " Guidelines on Safety in Road Construction Zones"

(1.8) IRC:15-2002, "Standard Specifications and Code of Practice for Construction of Concrete Roads (Third Revision)

(1.9) IRC:58-2002, "Guidelines for the Design of Plain Jointed Rigid Pavements for Highways" (Second Revision)

(1.10) IRC:SP:16-2004, "Guidelines for Surface Evenness of Highway Pavements"

(1.11) IRC:57-2006, "Recommended Practice for Sealing of Joints in Concrete Pavements" (First Revision)

(1.12) IRC:43-1972, "Recommended Practice for Tools, Equipment and Appliances for Concrete Pavement Construction"

(1.13) IS:11433 (Part 1) 1985: Specification for One Part Gun-Grade Polysulphide Based Joint Sealants

(1.14) IS:516 Methods of Test for Strength of Concrete
Where, IRC = Indian Roads Congress
IS = Bureau of Indian Standards

A.2. List of AASHTO, British and ASTM Standards

(2.1) AASHTO M 173, Concrete Joint Sealer, Hot Poured Elastic Type

(2.2) AASHTO M 282, Joint Sealant, Hot poured, Elastomeric Type

(2.3) AASHTO M 301, Joint Sealant, Hot poured for Concrete and Asphalt pavements

(2.4) ASTM C 39, Compressive strength of cylindrical concrete specimens

(2.5) ASTM C 150, Portland Cement

(2.6) ASTM D 1190 Concrete joint sealer, Hot Applied Elastic Type

(2.7) ASTM E 274, Skid Resistance of Paved Surface Using Full Scale Tire

(2.8) ASTM E 950, Measuring Longitudinal Profile with an Accelerometer

(2.9) ASTM E 1364, Measuring Road Roughness by Static Level Method

(2.10) ASTM D 3405, Joint Sealants, Hot Applied for Concrete

(2.11) ASTM D 3406, Joint Sealants, Hot Applied Electrometric Type for Portland Cement Concrete

(2.12) ASTM D-3575, Flexible Cellular Materials (For Sealant Backing Rods) made from Olefin Polymers

(2.13) ASTM D 5893, Cold Applied Single Component Chemically Curing Silicone

(2.14) ASTM D 6690 (part 1), Joint and crack sealant, Hot Applied, for Concrete and Asphalt Pavements

(2.15) BS:5212 (part 2), Cold Cured Joint Sealants for Concrete Pavements

(2.16) BS:7542 Method of Test for Curing Compound for Concrete

(2.17) AASTHO-AGC-ARTBA Task Force-36 "The Use and State –of-The-Practice of Fiber Reinforced Concrete"

Where, AASHTO = American Association of State Highways and Transportation Officials
ASTM = American Society for Testing and Materials

A.3. List of Other References

(3.1) Aerodrome Design Manual (DoC 9157-AN/901) Part 3 – Pavements Second Edition 1983

(3.2) H. S. Mildenhall, G. D. S. Northcott, Department of Transport, Cement and Concrete Association,1986, A Manual for the Maintenance and Repair of Concrete Roads, London, HMSO

(3.3) Committee of State Road Authorities, Pretoria, South Africa, 1990, Standard Nomenclature and Methods for Describing the Condition of Jointed Concrete Pavements, Technical Recommendations for Highways, Draft TRH19:1989

(3.4) Mohamed Y. Shahin, 1994, Pavement Management for Airports, Roads and Parking Lots, Chapman & Hall, New York, London

(3.5) Gerald F. Voigt, 2000, Specification Synthesis and Recommendation for Repairing

Uncontrolled Cracks that Occur during Concrete Pavement Construction, American Pavement Concrete Association (ACPA)

(3.6) US Federal Highway Administration, Report No.FHWA-01-00080 "Repair and Rehabilitation of Concrete Pavements", Sept 2004

(3.7) US Federal Highway Administration, Technical Brief No. FHWA-IF-06-005 " Concrete Pavement Rehabilitation and Preservation Treatments", November 2005

(3.8) US Federal Highway Administration, Concrete pavement Rehabilitation Guide for Diamond Grinding, May 2006

A.4. List of ACPA Standards

(4.1) TB018P—"Slab Stabilization Guidelines for Concrete Pavements"

(4.2) TB002.02P—" Guidelines for Full Depth Repair"

(4.3) TB008.01P—"Diamond Grinding and Concrete Pavement Restoration"

(4.4) TB020.02P—"The Concrete Pavement Restoration Guide"

(4.5) TB016.01P "Early Cracking of Concrete Pavement—Causes and Repairs"

Where ACPA = American Concrete Pavement Association

APPENDIX-B

MIX CHARACTERISTICS FOR EOT* PROJECTS

Year	Place	Mixture Proportions	Compressive Strength (ASTM) converted to Cube strength (MPa) at different age	Flexural Strength (MPa)	Notes
1990	Northampton County, Virginia, USA	Cement (type I, ASTM): 445 kg/cu.m W/C : 0.42 Coarse aggregate: 1113 kg/cu.m Fine aggregate: 620 kg/cu.m Max. aggregate size: 25 mm Water reducer: AASHTO M 194 Air entrained: 5.5 %	18 hour: 32 24 hour:36 7 days: 50 28 days: 60	28 days: 5.6	Opened to traffic after 58 hour; traffic amount of 240 equivalent single axle load per day
1991	Dallas County, Iowa, USA	Cement: 298 kg/cu.m Fly ash: 56 kg/cu.m Coarse aggregates: 914 kg/cu.m Fine aggregate: 933 kg/cu.m Water reducer: 2.6 ml/kg Air entrained: 0.56 ml/kg	28 days: 34	28 days: 4.7	-
1991	Louisville Kentucky, USA	Cement (type I, ASTM): 475kg/cu.m W/C : 0.33 Coarse aggregate: 1067 kg/cu.m Natural sand : 948 kg/cu.m Water reducer: (ASTM C-494): 1.1 kg/100 kg Air entrained: 4 to 6% Polypropylene fibres:1.78 kg/cu.m	18 hour: 34	-	Waste disposal facility: 90 trucks per day; opened to traffic after 37 hour
1994	Gerogetown Kentucky, USA	Cement(type I): 475 kg/cu.m W/C : 0.32 60% - 40% ratio of coarse aggregate and natural sand water reducer:0.98 ml/100 kg Air entrained: 5.5 %	24 hour: 31	-	Stretch Intersection
1994	State Route 21, Iowa, USA	Cement: 340 kg/cu.m W/C : 0.43 Coarse aggregate: 986 kg/cu.m Fine aggregate: 809 kg/cu.m Air entrained: 6 % Synthetic fibers: 1.36 kg/cu.m	-	-	Opening to traffic after 5-7 days

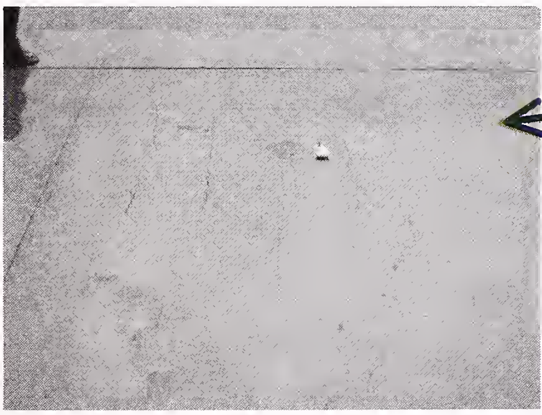
* EOT – Early Opening to Traffic Concrete.

Year	Place	Mixture Proportions	Compressive Strength (ASTM) converted to Cube strength (MPa) at different age	Flexural Strength (MPa)	Notes
1995	Leawood Kansa, USA	Cement (type I): 363 kg/cu.m W/C : 0.37 Coarse aggregate: 1026 kg/cu.m Fine aggregate: 798 kg/cu.m Max. aggregate size: 25 mm Air entrained: 6.5% Synthetic fibers: 1.36 kg/cu.m	24 hour: 26	-	Opened to traffic after 24 hour; mixed traffic of 25,000 vehicles per day
1995	Tennessee & Dckalb Co., GA, USA	Cement: 474 kg/cmW/C : 0.35 Coarse aggregate: 1008 kg/cu.m Fine aggregate: 730 kg/cu.m Synthetic fibers: 1.36 kg/cu.m	24 hour: 43 (achieved)	-	-
1995	Lexington, Kentucky, USA	Cement (type I): 475 kg/cu.m Coarse aggregate: 1067 kg/cu.m Natural sand: 948 kg/cu.m Max. aggregate size: 25 mm Water reducer: (ASTM C-494, type F): 0.98 ml/ 100 kg Air entrained: 5 % Synthetic fibers: 1.36 kg/cu.m	24 hour: 30 36 hour: 42 48 hour: 44 7 days: 56 28 days:64	24 hour: 5.236 hour: 5.828 days:7.1	

APPENDIX-C

PHOTOGRAPHS ILLUSTRATING COMMON TYPES OF DEFECTS AND SUGGESTED TYPICAL REPAIR TECHNIQUES AS PER THE DISTRESS SEVERITY

 Photo 1) - Blowup and Transverse Cracking	FULL DEPTH REPAIR (Width of Repair 1.5m minimum) Note: example illustrated caused by Blowup Severity Rating 5 Recommended Treatment As Above
 Photo 2) - Deep Corner Break	One Corner Break EPOXY CONCRETE REPAIR (LOCAL) Two Corner Breaks FULL DEPTH REPAIR (1.5m minimum) Note: Severity Rating 4 is illustrated in example Recommended Treatment as Above
 Photo 3) - Shallow Corner Break	SEAL WITH LOW VISCOSITY EPOXY See Para & Figure 5.1 Note: Severity Rating 2 is illustrated in example Recommended Treatment as Above

 **Severity Rating <** **3CROSS-STICHING** See Figure 5.1 (Para) Photo 4) - Longitudinal Crack	Severity Rating 3 or more WHOLE SLAB REPLACEMENT Note: The condition of the slabs illustrated here treated with Cross-Stitching deteriorated further under traffic after monitoring for 6 months . All cracked slabs were finally replaced in total (whole full depth) during the DLP. Recommended Treatment As Above.
 Photo 5) - Multiple Connecting Cracks	WHOLE SLAB REPLACEMENT Note: Severity Rating 3 is illustrated in example. Recommended Treatment As Above
 Photo 6) - Discrete Plastic Shrinkage Cracks	WIND DIRECTION SEAL WITH LOW VISCOSITY EPOXY Note: Severity Rating 2 is illustrated in example Recommended Treatment As Above

<table>
<tr><td>
Photo 7 a) - Transverse Crack Near Joint</td><td>FULL DEPTH REPAIR
(Width = 1.5m, Minimum)

Note: Severity Rating 4
is illustrated in example

Recommended Treatment As Above</td></tr>
<tr><td>
Photo 7 b) - Transverse Crack Near Middle (1/3rd)</td><td>A) WHOLE SLAB REPLACEMENT
For New Construction (DLP)
or
B) CHIP AND SEAL
MONITOR AS WORKING CRACK
SHORT TERM MEASURE
For Old Concrete Panels
Note: Severity Rating 4
is illustrated in example

Recommended Treatment As Above</td></tr>
<tr><td>
Photo 8) Working Crack</td><td>ROUTE GROOVE AND APPLY FLEXIBLE
SEALANT

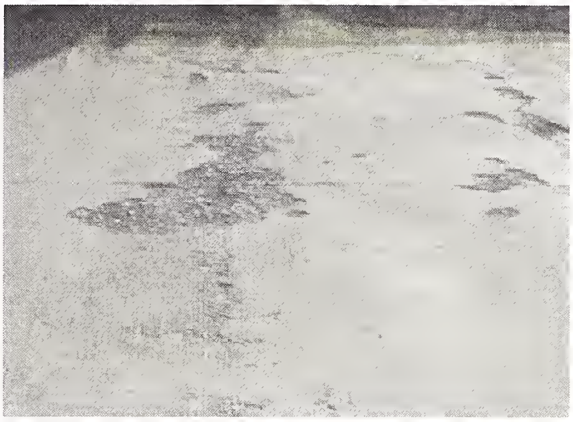
MONITOR PEFORMANCE

Note: Example illustrated is treatment on 50 year old concrete slabs constructed (Oct/1952) in medium trafficked urban environment.

Recommended Short Term Measure</td></tr>
</table>

 Photo 9 - Drop Off	SCARIFY AND FILL UP WITH A WEAR RESISTANT TRAFFICABLE GRAVEL (CBR > 30, PI in range 3 - 12) When Dropoff in any 100m stretch > 40 mm For NH/SH > 70 mm For Other Roads See Table 4.4 Recommended Treatment
 Photo 10) - Impressions Early Traffic Damage	Severity rating < 2 DO NOTHING Severity Rating > 3 LOCAL EPOXY MORTAR REPAIR To DEPTH 65 mm with 20 mm Drill Holes for "Key" Recommended Treatment
 Photo 11) Manhole / Inlet Cracking Failure	Cracking and/or faulting caused by restrained thermic movements around or settlement below a manhole or inlet. Severity Rating > 4 FULL DEPTH REPAIR IN REGULAR SHAPE WITH REINFORCEMENT Recommended Treatment

 Photo 12) - Pop Out	EPOXY MORTAR REPAIR See Figure 5.1 Note: Severity Rating 3 is illustrated in example Recommended Treatment As Above
 Photo 13) - Punchout (CRCP only)	SHAPE MERGEFORMAT Water trapped under edge of CRCP at Matching point with Paved Shoulder causing cracking and punching out under heavy traffic loading IMPROVE DRAINAGE BELOW BASE AND RECONSTRUCT FULL DEPTH PATCH Recommended Treatment As Above
 Photo 14) - Ravelling (lose of laitance/fine aggregates in surface)	Severity Rating < 4 DO NOTHING Severity Rating 5 or more WHOLE SLAB REPLACEMENT For New Construction (DLP) MILL & PLACE BONDED OVERLAY Trial For Old Construction Note: Severity Rating 5 is illustrated in example Recommended Treatment

<table>
<tr><td>
Photo 15) - Scaling</td><td>Severity Rating < 2
PARTIAL DEPTH REPAIR

Severity Rating 3 or more

WHOLE SLAB REPLACEMENT

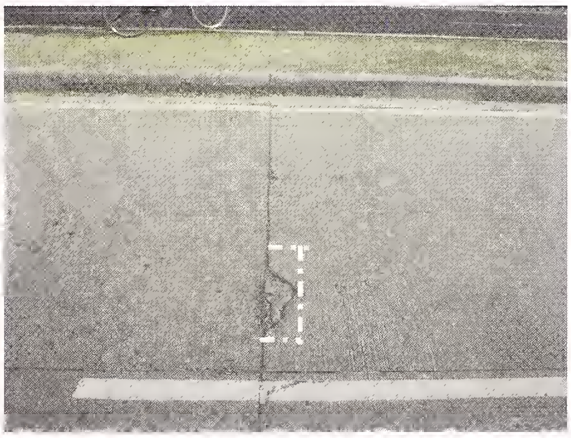
Note: Severity Rating 3
is illustrated in example

Recommended Treatment</td></tr>
<tr><td>
Photo 16) Joint Sealant Failure -</td><td>Cause of adhesion failure : loss of sealant bond/adhesion to sides caused by separation of slabs.

Severity rating < 2
DO NOTHING

Severity Rating > 3
RESEAL WHERE FAILURE / DAMAGE EXCEEDS 25% OF JOINT LENGTH

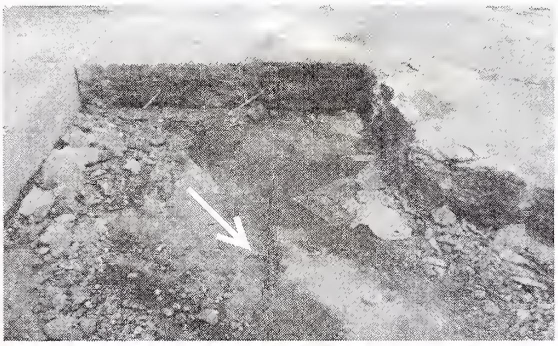
Note: Example illustrated is Severity Rating 4 at a Longitudinal Joint

Recommended Treatment</td></tr>
<tr><td>
Photo 17) - Shallow Spalling at Joint</td><td>PARTIAL DEPTH REPAIR
Note: Severity Rating 4
is illustrated in example (> 60 x 10 cm)

<table><tr><th>Maximum Surface Area</th><th>Minimum Depth</th><th>Patch Material</th></tr><tr><td>< 0.5 m²</td><td>30 mm</td><td>Elastomeric Concrete</td></tr><tr><td>> 0.5m²</td><td>100 mm</td><td>Epoxy Concrete</td></tr></table>
Recommended Treatment</td></tr>
</table>

 Photo 18) Deep Spalling at Joints	Cause: Misalignment of dowel bars, Inadequate compaction and/or Compression Failure FULL DEPTH REPAIR (1.5m) EACH SIDE OF JOINT Recommended Treatment
 Photo 20) - Cracking and Scaling at Construction Joint	Cause : Inadequate compaction and Finishing 2nd Days concrete versus 1st Days concrete. Deficiencies vide: - Levelling - Finishing - Compaction FULL DEPTH REPAIR (1.5m minimum) ONE SIDE ONLY Recommended Treatment
 Photo 21) - Expansion Joint Damage	PARTIAL DEPTH REPAIR (MINIMUM WIDTH 100mm x 65mm DEEP) Recommended Treatment

<table>
<tr><td>
Photo 22) Shattered Slabs</td><td>Severity Rating 5
WHOLE SLAB REPLACEMENT

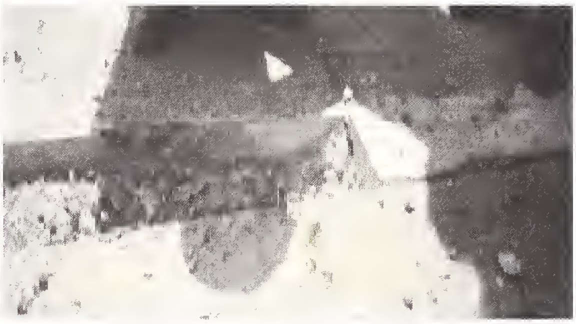
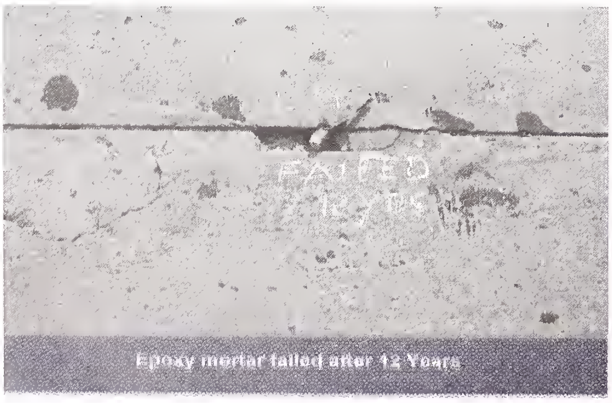
Recommended Treatment</td></tr>
<tr><td>
Photo 23) Cracking of DLC Below PQC</td><td>WHOLE SLAB REPLACEMENT
With Reinforcement added in Top
(as precaution against reflective cracking)

DLC only requires replacement if in a shattered state.

Recommended Treatment</td></tr>
<tr><td>
Photo 23) Compressive Seal - Loosening</td><td>Cause: Adhesion Failure and/or Vandalism

SEAL TO SECURE ENDS
WITH COMBATABLE LIQUID
SEALANT.

Recommended Treatment</td></tr>
</table>

 Photo 24) Spalling along the Joint	The unsound area will be marked with colored marker after sounding with hand held hammer. It will Saw Cut with light weight Concrete Saw cutter. The chisel will also be used to cut & take out the debris. The pit will be air cleaned and filled with epoxy concrete/ PCC depending upon depth of spall. Recommended treatment
 Photo 25) Shallow Corner Break	Full Depth repair after removing unsound and cracked concrete. Recommended treatment
 Photo 26) Pit Cut out for Partial Depth Repair	Fill the Pit with Epoxy Concrete/ Quick Setting Cementitious Material depending upon the depth of the cut Recommended treatment
 Photo 27) Partial Depth Repair Failure	Deepen & Widen the Pit and repair with quick setting Cementitious Material Recommended treatment

APPENDIX-D

TREATMENT AND UPGRADING OF ERODED SOFT EARTHEN SHOULDERS

The narrow soft earthen shoulders typically observed on State and National Highway projects are an important design shortcoming.

The MoRT&H Clause 305.2.1 provides for a mixture of soil, moorum, and gravel but the designers generally keep the specification for the earthen shoulder the same as for sub-grade material as in the case illustrated below which specifies a material satisfying the design CBR of 6%.

Photograph 1 - Erosion, Wear and Tear of Soft Earthen Shoulder. Trucks Preferring to Park on Outer Lane

Shoulders should however provide lateral support to the edges of the pavement, be of sufficient width and strength to support the parking of heavy vehicles under all weather conditions, shed off water, be durable and protect the lateral sub-drainage to the pavement below. Soft soil shoulders cannot comply with such requirements.

Soft shoulders are easily eroded. After erosion they do not provide comfortable walk for pedestrians, cannot provide a margin for error to avoid accidents nor be used by vehicles for parking. The erosion of shoulders is both superficial and internal and such erosion seriously undermines the embankments if left untreated which is often the case in rural areas.

Erosion is often more severe at the interface of paved to unpaved shoulder. Transverse erosion/gullying of shoulders can develop by piping and often be concealed by poor control of overgrowth.

The severity of soft shoulder's erosion will increase after every rainy season and a situation will be created where the edges of the flexible (and the rigid) pavement will be seriously undermined by lack of lateral support. (Photograph 2).

Photograph 2 - Complete Erosion and Undermining of Rigid Pavement has Commenced

Proper treatment can be provided by turfing, brick on edge or from soil aggregate mixture.

Turfing the shoulder and whole side slope may prove satisfactory under certain climatic conditions as illustrated in the Photograph 3.

Photograph 3 - Turfing on Shoulder and Side Slope

Alternatively, soil aggregate mixtures may be procured from :

(1) borrow areas and mixed together so to comply with the specification recommended in the Table below,

or

(2) salvaged pavement sub-base and base materials recovered from the old (2-lane) pavement during the upgrading/widening to 4/6-lanes screened to discard oversized material (75%) and mixed together with a local moorum (25%) so to generally comply with a close graded GSB (Grading I) material. PI in the range 3 - 12%. (Photograph 4).

Photograph 4 - Construction of Hard Shoulder with Recycled Sub-Base/Base Material Recovered from Existing Highway Mixed with Local Red Moorum (CBR>30)

It is further recommended that where the condition of existing soft shoulders is poor and unsatisfactory, the top 20 cm be replaced by hard granular shoulders with CBR > 30 as above as part of the engineering improvements proposed for the short term operations and maintenance contracts.

Recommended specification for special surface course gravel suitable for a trafficable unpaved shoulder are based on the materials described in the Technical Paper by NB. Lal and S.C.Sharma(Ref: 1).

Table D.1. Typical Specification for a Trafficable Surface Course Gravel*

Grading	Grading 1 - (% passing)	Grading 2 - (% passing) Suitable for mixture of salvaged base/sub-base (75%) and moorum (25%)
75		100
53		80 -100
26.5	100	55 - 90
19	97 - 100	
9.5		35 - 65
4.75	41 - 71	25 -55
2.36		20 - 40
0.425	12 - 28	10 - 25
0.075	9 - 16	3 - 10
Soaked CBR	>30	>30
PI in the range 3 - 12 according to the climatic conditions		

Alternatively, brick-on-edge paving complying with local State PWD specifications will provide a more durable but slightly more expensive solution. (Photograph 5).

Photograph 5 - Construction of Brick on Edge (Paved Shoulder)

Reference:

1. Technical Paper by N.B. Lal and S.C.Sharma as published by Indian Roads Congress "International Seminar on Innovations in Construction and Maintenance of Flexible Pavements, Agra 2-4 September 2006", Pages 4-21 to 4-36.

APPENDIX-E

DETAILS OF MU-METER AND BRITISH PENDULUM TESTER

Mu-Meter: It is a battery-powered equipment used as a continuous friction measuring and reporting system, mainly designed for testing road surfaces airport runways and taxiways. Features like fully shock absorbed suspension, aerodynamic fairings; and low centre of gravity ensure that the laterally loaded wheels remain in firm contact with the road surface at all times, even at high speeds.

This equipment consists of a small three-wheeled trailer (weight 254 kg) incorporating electronic measuring systems which operate in conjuctions with a computer carried in the chosen towing vehicle. The trailer unit comprises of a triangular frame on which two friction measuring wheels are mounted as shown in **Fig. 1.** The built-in recorder of Mu-meter is shown in **Fig. 2.** The rear wheel which drives the recorder also measures the distance. It measures the sideway coefficient of friction generated between the test surface and the smooth tread tyres operating at 7.5 degrees angle to the directions of travel under the wet condition. The speed of measurement for normal recording is 64 km/hr. In Mu-meter, the force required to slide the tyre is divided by the wheel

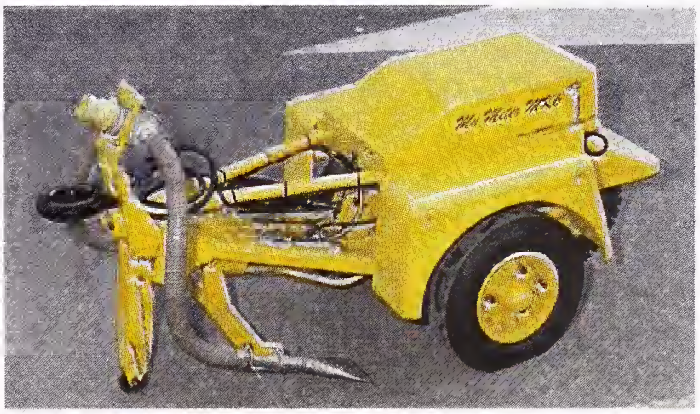


Fig. 1. Mu-Meter Equipment

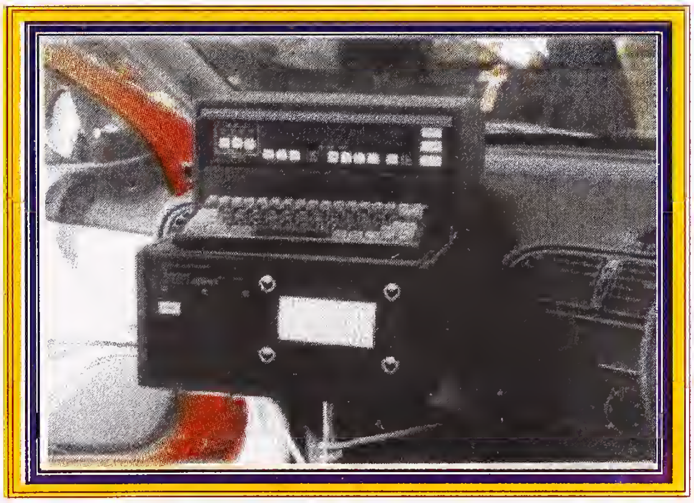


Fig. 2. Recorder of Mu-Meter Data

load and multiplied by 100 to calculate the skid number. The skid resistance numbers for various traffic speeds are indicated in **Table 1.**

Table 1 Skid Resistance No. at different Speeds of Vehicles

Minimum SN	Traffic Speed (km/h)
36	50
33	65
32	80
31	95
31	110

Ref: ICPI (Inter-locking Concrete Pavement Institute) Spec. No. 13 1998 (Revised 2004), USA

British Pendulum Tester: The British pendulum test is a common procedure for laboratory as well as field measurement of the low-speed friction of a road surface material. It is widely suggested that the measured low-speed friction is largely governed by the surface microtexture of the road material, and many researchers and practitioners have considered the friction measurements made by the British pendulum test to be an indirect form of measurement of available microtexture of the road material. The test results demonstrated that the low-speed friction measurements by the British pendulum tester (as shown in **Fig. 3**) were significantly affected by test surface macrotexture. British pendulum test may not produce a correct assessment of the skid resistance of the true road surface. The value measured by the tester is expressed in terms of British Pendulum Number (BPN). British Pendulum Tester gives higher skid resistance rating than dynamic tyre and trailer test. British Pendulum Number rating between 45 and 55 indicates a satisfactory surface in only favourable weather and vehicle conditions. Rating of 55 or greater indicates generally acceptable skid resistance (SN) in all conditions. BPN 65 and above rating indicates a good to excellent skid resistance in all conditions. The BPN measurements are taken on wet surface. These days, Digital British Pendulum Tester (as shown in **Fig. 4**) for measuring skid resistance of the surface is also available.

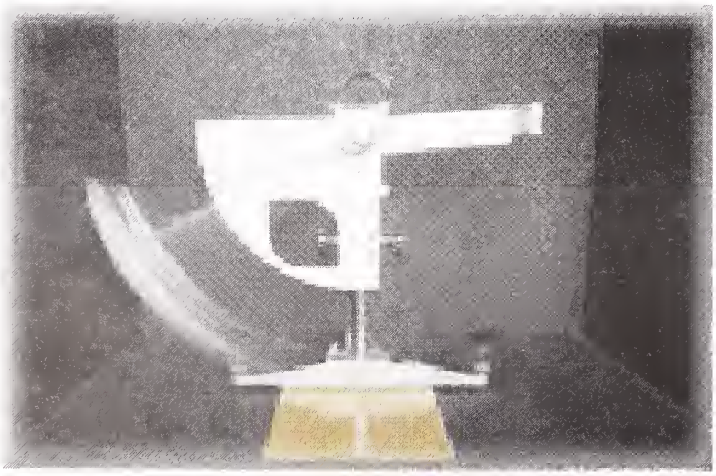


Fig. 3. Analog British Pendulum Tester

Fig. 4. Digital British Pendulum Tester

(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the code/guidelines/manual, etc. from the date specified therein)